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ABSTRACT

Theory and research regarding four levels of concept attainment and three uses of concepts as specified by the conceptual learning and development (CLD) model are described. The strategy and objectives of a longitudinal assessment of children's conceptual learning and development are presented. Perspective is provided regarding the role of the present cross-sectional study in the longitudinal assessment. For the present study, assessment batteries were developed to assess each child's level of concept attainment and also the related use of the concepts equilateral triangle and cutting tool. Both batteries were designed as paper-and-pencil tasks and administered to 100 children enrolled in each of four grades: kindergarten, third, sixth, and ninth. Predictions based on the model about children's conceptual development were strongly supported across both concepts. The two concepts were attained in an invariant sequence according to four successive levels: concrete, identity, classificatory, and formal. As the concepts were attained to higher levels they were used increasingly (a) in cognizing supraordinate-subordinate relationships in a hierarchy where the attained concept was an element of the hierarchy, (b) in understanding principles that stated a relationship between the attained concept and one or more other concepts, and (c) in solving problems that required the use of the particular concept. Havi*g the labels of the concept and of its defining attributes facilitated (a) attainment of the concept and (b) mastery of the three uses of the concept. (Author)

RESEARCH
COGNITIVE
LEARNING
DEVELOPMENT

Technical Report No. 288

FIRST CROSS-SECTIONAL STUDY OF ATTAINMENT OF THE CONCEPTS EQUILATERAL TRIANGLE AND CUTTING TOOL BY CHILDREN AGE 5 TO 16 OF CITY B

by

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Report from the Program on
Children's Learning and Development

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Statement of Focus

Individually Guided Education (IGE) is a new comprehensive system of elementary education. The following components of the IGE system are in varying stages of development and implementation: a new organization for instruction and related administrative arrangements; a model of instructional programing for the individual student; and curriculum components in prereading, reading, mathematics, motivation, and environmental education. The development of other curriculum components, of a system for managing instruction by computer, and of instructional strategies is needed to complete the system. Continuing programmatic research is required to provide a sound knowledge base for the components under development and for improved second generation components. Finally, systematic implementation is essential so that the products will function properly in the IGE schools.

The Center plans and carries out the research, development, and implementation components of its IGE program in this sequence: (1) identify the needs and delimit the component problem area; (2) assess the possible constraints—financial resources and availability of staff; (3) formulate general plans and specific procedures for solving the problems; (4) secure and allocate human and material resources to carry out the plans; (5) provide for effective communication among personnel and efficient management of activities and resources; and (6) evaluate the effectiveness of each activity and its contribution to the total program and correct any difficulties through feedback mechanisms and appropriate management techniques.

A self-renewing system of elementary education is projected in each participating elementary school, i.e., one which is less dependent on external sources for direction and is more responsive to the needs of the children attending each particular school. In the IGE schools, Center-developed and other curriculum products compatible with the Center's instructional programing model will lead to higher student achievement and self-direction in learning and in conduct and also to higher morale and job satisfaction among educational personnel. Each developmental product makes its unique contribution to IGE as it is implemented in the schools. The various research components add to the knowledge of Center practitioners, developers, and theorists.

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Abstract

Theory and research regarding four levels of concept attainment and three uses of concepts as specified by the conceptual learning and development (CLD) model are described. The strategy and objectives of a longitudinal assessment of children's conceptual learning and development are presented. Perspective is provided regarding the role of the present cross-sectional study in the longitudinal assessment.

For the present study, assessment batteries were developed to assess each child's level of concept attainment and also the related use of the concepts equilateral triangle and cutting tool. Both batteries were designed as paper-and-pencil tasks and administered to 100 children enrolled in each of four grades: kindergarten, third, sixth, and ninth.

Predictions based on the model about children's conceptual development were strongly supported across both concepts:

1. The two concepts were attained in an invariant sequence according to four successive levels: concrete, identity, classificatory, and formal.

2. As the concepts were attained to higher levels they were used increasingly (a) in cognizing supraordinate-subordinate relationships in a hierarchy where the attained concept was an element of the hierarchy, (b) in understanding principles that stated a relationship between the attained concept and one or more other concepts, and (c) in solving problems that required the use of the particular concept.

3. Having the labels of the concept and of its defining attributes facilitated (a) attainment of the concept and (b) mastery of the three uses of the concept.

I
Introduction: Concepts and Concept Learning

Individuals at all levels of human development are constantly learning new concepts and extending and using old concepts in new situations. It is apparent, however, that an individual's level of mastery of a particular concept will differ depending upon his experiences with concept instances and his ability to perform the cognitive operations. For example, a four-year-old child and a biologist may both have a concept of tree; although both may perform equally well when asked to identify a few obvious examples and nonexamples of tree, their concepts differ markedly. Despite the large difference in level of understanding, concepts are the fundamental agents of thought for human beings from early childhood through adulthood.

A substantial amount of research on concept learning has been completed during the past two decades. Two types of research have been conducted, one dealing with the internal and external conditions of concept learning and another type involving the behavioral analysis of learning concepts related to various subject-matter fields. Sufficient knowledge has accrued so that Klausmeier, Ghatala, and Frayer (1974) were able to formulate a model that specifies and describes the cognitive operations involved in the attainment of concepts at specifiable levels of mastery by individuals whose abilities change in predictable ways with age. (We use "age" as a shorthand term to indicate the product of learning and maturation; age, per se, is not considered a determining factor of how well individuals can perform.)

An analytical descriptive model of conceptual learning and development (CLD model) was initially formulated by Klausmeier (1971) and described more fully by Klausmeier, Ghatala, and Frayer (1974). The model defines four levels of concept attainment and the possible uses and extensions of attained concepts, specifies the cognitive operations involved in learning concepts at each of the four levels, and postulates internal and external conditions of learning related to the specified levels. The levels of concept mastery, the operations, and the conditions of learning have been identified through behavioral analyses of concept learning tasks and through empirical research in laboratory and school settings carried out at the Wisconsin Research and Development Center for Cognitive Learning and other research laboratories.

The Nature of Concepts

The word concept is used by Klausmeier, Ghatala, and Frayer (1974) to designate mental constructs of individuals and also identifiable public entities that comprise part of the substance of the various disciplines. Thus, concept is used appropriately in two different contexts just as many other English words are. A concept is defined as ordered information about the properties of one or more things--objects, events, or processes--that enables any particular thing or class of things to be differentiated from, and also related to, other things or classes of things.

In connection with concepts as mental constructs it is noted that each maturing individual attains concepts according to his unique learning experiences and maturational pattern. In turn, the concepts he attains are used in his thinking about the physical and social world.

Concepts as public entities are defined as organized information corresponding to the meaning of words. Carroll (1964) related concepts, words, and word meanings in the following way. Words in a language can be thought of as a series of spoken or written entities. There are meanings for words that can be thought of as a standard of communicative behavior that is shared by those who speak a language. Finally, there are concepts--that is, the classes of experiences formed in individuals either independently of language processes or in close dependence on language processes. Putting the three together, Carroll stated: "A 'meaning' of a word is, therefore, a societally standardized concept, and when we say that a word stands for or names a concept it is understood that we are speaking of concepts that are shared among members of a speech community [1964, p. 187]."

At the inception of a large programmatic research effort dealing with concept learning and instruction, Klausmeier, Davis, Ramsay, Fredrick, and Davies (1965) formulated a conception of concept in terms of defining attributes common to many concepts from various disciplines. Klausmeier, Ghatala, and Frayer (1974) further refined the definition by specifying eight attributes of concepts: learnability, usability, validity, generality, power, structure, instance numerousness, and instance perceptibility. Other researchers and subject-matter specialists are also treating concepts in terms of defining attributes. For example, Flavell (1970) indicated that a formal definition of concept in terms of its defining attributes is useful in specifying what concepts are and are not and also in identifying the great variability among concepts. Markle and Tiemann (1969) and Tennyson and Boutwell (1971) have shown that the external conditions of concept learning can be delineated through research that starts with a systematic analysis of the attributes of the particular concepts used in the research. Scholars at the Wisconsin R & D Center demonstrated that analysis of concepts in terms of their relevant and irrelevant attributes is useful in clarifying the meanings of the concepts drawn from four disciplines: language arts--Golub, Fredrick, Nelson, and Frayer (1971); mathematics--Romberg, Steitz, and Frayer (1971); science--Voelker, Sorenson, and Frayer (1971); and social studies--Tabachnick, Weible, and Frayer (1970).

The CLD model deals primarily with concepts represented by words that can be defined in terms of attributes, although some concepts are defined on other bases, including through the use of synonyms and antonyms. Further, not all words potentially definable in terms of attributes are so defined, even in unabridged dictionaries. Therefore, the researcher and also the developer of curriculum materials must ascertain the defining attributes independently or cooperatively with scholars from the various desciplines.

An Overview of the Conceptual Learning and Development Model

Figure 1 shows the structure of the model. Four levels in the attainment of the same concept at successively higher levels are outlined. The four successive levels are concrete, iden- sificatory, and formal. As a con- is attained by an individual at the successive levels it becomes increasingly usable and valid, as defined earlier.

A second part of Figure 1 shows the ways in which concepts may be extended and used. Concepts acquired at only the concrete and identity levels can be used to solve simple problems that require only the relating of obvious sensory perceptions. For example, to save time, or for some other reason, a child may walk diagonally across a rectangular block rather than remaining on the sidewalk and walking around a rner of the block. He need not have attained the concepts of distance, angle, diagonal, or straight line at the classificatory level.

Concepts acquired at the classificatory and formal levels may be generalized to newly encountered instances, related to other concepts, and used in problem-solving situations. Here we are concerned both with transfer of learning and the use of concepts in thinking.

Figure 1 also indicates the operations involved in attaining a concept at each level. Attending to and discriminating objects and then remembering what was discriminated are involved in attaining a concept at the concrete level. The same operations are also involved at each subsequent level and are supplemented with the higher-level operations of generalizing, hypothesizing, and evaluating.

Although some of the same operations are postulated to occur at various levels, what is operated on and remembered changes with the attainment of the successively higher levels. That is, the operations are carried out on more sharply differentiated and abstracted stimulus properties at the four successive levels.

By focusing on the attainment of successively higher levels of the same concept, we are able to clarify the short-term learning conditions at each level and to describe conceptual development over long time intervals. Thus, the model provides a basis for organizing knowledge and carrying out research related to both the external and internal conditions of learning at each of the four levels.

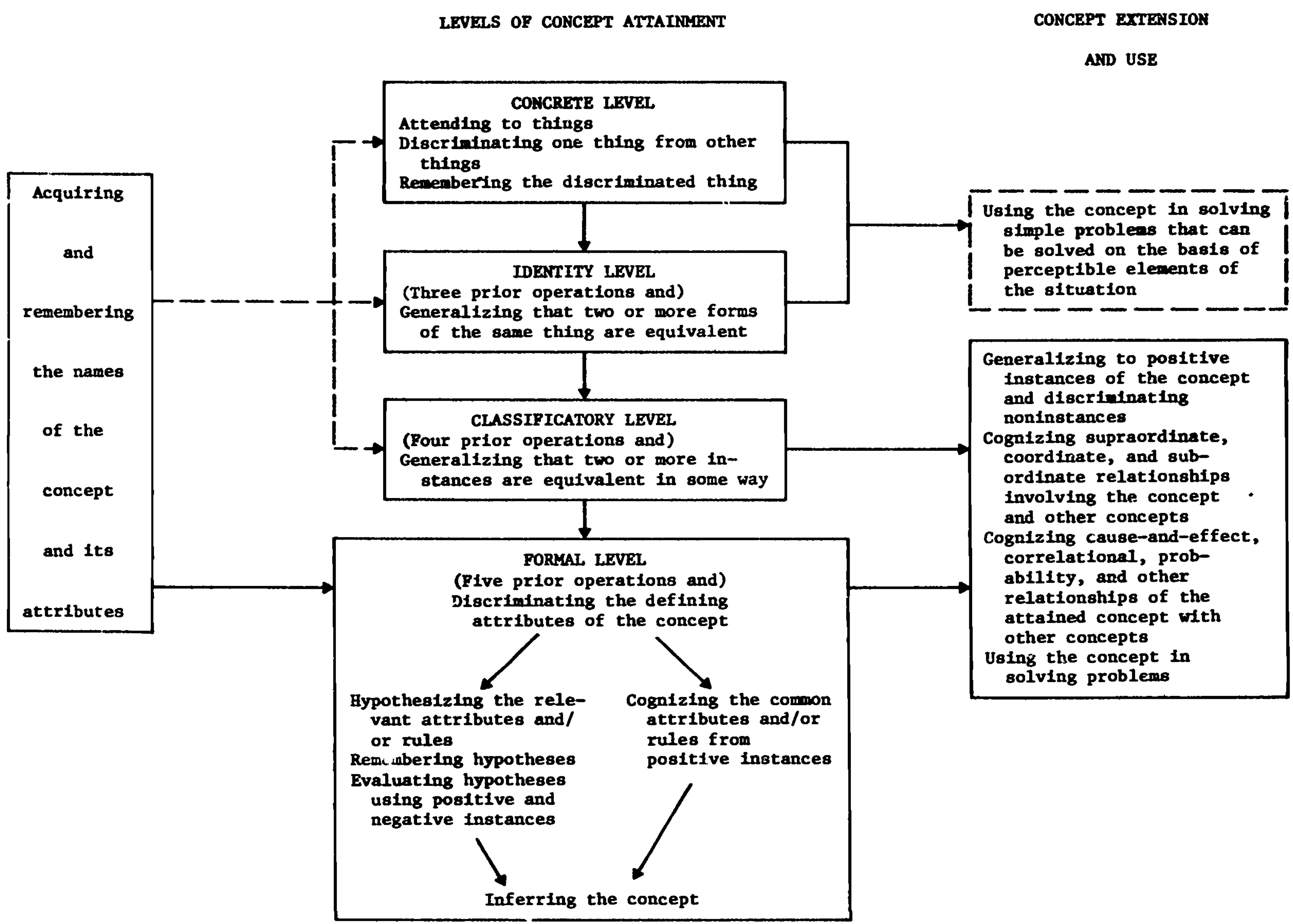

Figure 1. Cognitive operations in concept learning.

The fourth part of the model shows that acquiring and remembering the name of the concept may come at any of the four levels. The solid line indicates that being able to name the concept and its relevant attributes is essential to attaining concepts at the formal level. The broken lines indicate that an individual may acquire the name at about the same time he first attains the concept at lower levels but that this is not requisite. For example, a young child might attain a concept at all three lower levels but not the concept name. The younger the child is upon attaining the concept, the less likely he is to have the name for it.

At this time, we shall delimit the substantive domain that we are treating. The model in its totality describes the four levels of concept attainment and uses of the same concept rather than each of four kinds of concepts. The four levels apply to the many concepts that are or can be defined in terms of attributes and which have actual perceptible instances or readily constructed representations of instances. We have already cited a few examples of this kind, including all the concepts comprising the plant kingdom and the animal kingdom. However, the operations at each level are intended to be applicable also to different kinds of concepts, some of which, because of their nature, are not attainable at all four levels. We can specify these kinds of concepts and the levels at which they can be attained.

There are some concepts for which there is only one instance such as the earth's moon and Abraham Lincoln and some that have many identical instances, for example, inch and pound. Related to Figure 1, such single-instance or identical-instance concepts which have defining attributes can be attained at the concrete, identity, and formal levels, but not at the classificatory level. By our definition of classificatory level, there must be at least two nonidentical instances that can be placed in the same class. Therefore, some concepts cannot be attained at the classificatory level.

Other concepts are of such low validity that there may not be agreement as to the defining attributes, for example, beauty and morality. Concepts such as these might be learned at the three lower levels but not at the formal level.

Finally, there are concepts with no perceptible instances, such as infinity and atom. These cannot be learned at the three lower levels but might be learned at the formal level.

Returning to the four levels given in Figure 1, we postulate that attaining a concept at the four successively higher levels is the normative pattern for large numbers of individuals under two conditions. First, the concept is of the kind for which there are actual perceptible instances or readily constructed representations; and second, the individual has experiences with the instances or representations starting in early childhood. Furthermore, in order to proceed to the formal level, individuals must acquire labels for the concept and for its attributes. For example, the individual will have successively attained the concrete, identity, and classificatory levels of the concept plant before he describes and treats plant formally in terms of its defining attributes.

Children have direct experiences during preschool years with many things and attain concepts of these things at the first two levels. They also attain many concepts at the classificatory level and learn the societally accepted names for the concepts and their attributes through formal and informal instruction.

Earlier we indicated that some individuals, because of environmental conditions, may not encounter actual instances of a concept; rather, they experience instances only in verbal form. Thus, these individuals may attain a concept at either the classificatory or the formal level at the outset. It is also noted that the mature person, although capable of attaining a concept at the formal level, may stop at a lower level of attainment because of the way in which the perceptible instances are encountered or other conditions of learning.

Operations Related to Levels of Concept Attainment

Having considered the overall features of the model, we may take up the operations in more detail, starting with those pertaining to the concrete level.

Concrete Level

Attainment of a concept at the concrete level is inferred when the individual cognizes an object that he has encountered on a prior occasion. We use the term "operations" as Guilford (1967) does. Guilford has defined the operations of cognition, memory, productive thinking, and evaluation in terms of test performances. He stated that cognition must be related to the products cognized and he formally defined cognition as follows:

Cognition is awareness, immediate

discovery or rediscovery, or recognition of information in various forms; comprehension or understanding . . . The most general term, awareness, emphasizes having active information at the moment or in the present . . . the term, recognition, is applied to knowing the same particular on a second encounter . . . if cognition is practically instantaneous, call it recognition; if it comes with a slight delay, call it "immediate discovery;" [pp. 203-204]."

The first step in attaining this level is attending to an object and representing it internally. Woodruff (1961) pointed out that:

> All learning begins with some form of personal contact with actual objects, events, or circumstances. . . . The individual gives attention to some object. . . . Through a light wave, or a sound wave, or some form of direct contact with a sensory organ in the body, an impression is picked up and lodged in the mind [p. 66].

Gagné (1970) indicated that as the individual attends to an object, he discriminates it from other objects. Woodruff (1961) called the outcome of these attending and discriminating operations a concrete concept, a mental image of some real object experienced directly by the sense organs. The infant, for example, attends a large red ball and a white plastic bottle, discriminates each one, maintains a mental image of each, and cognizes each of the objects when experienced later.

The discrimination of objects involves attending to distinctive features that serve to distinguish the objects from one another. Thus, very early the child learns to respond to gross differences in such features of objects as size, shape, color. and texture. As the child matures, he becomes capable of making finer discriminations involving these and other features.

The attainment of a concept at the concrete level thus requires attending to the distinctive features of an object and forming a memory image which represents the object as a unique bundle of features. The concept at this level may or may not be associated with the concept label, depending on whether the label has been learned and remembered, and whether it has been associated with the concept.

The preceding analysis of the operations is attaining concepts at the concrete level is sufficiently comprehensive to include motoric experiencing of objects. That is, an object may be manipulated physically and represented enactively, as well as explored visually and represented iconically, to use Bruner's (1964) terminology. The model postulates that attending, discriminating, and remembering are involved in sensorimotor experiencing (to use the terms of Piaget, 1970) as well as in the visual perception of objects.

Identity Level

Attainment of a concept at the identity level is inferred when the individual cognizes an object as the same one previously encountered when observed from a different perspective or sensed in a different modality. For example, the child's making the same response to the family poodle when seen from straight ahead, from the side, and from various angles is evidence of his having attained the concept of poodle at the identity level. Whereas concept attainment at the concrete level involves only the discrimination of an object from other objects, attainment at the identy level involves both discriminating various forms of the same object from other objects and also generalizing the forms as equivalent. Generalizing is the new operation postulated to emerge as a result of learning and maturation that makes attainment at the identity level possible.

As noted earlier, there are some valid and powerful concepts, such as the English alphabet, for which there is only one instance but which can be represented in different ways, e.g., aurally and in printed form. These concepts are typically learned at the concrete and identity levels but not at the classificatory level. Therefore, individuals proceed directly from the identity to the formal level with this kind of concept.

Bruner, Goodnow, and Austin (1956) have pointed out that identity responses occur very early in life and that the capability to recognize identity may be innate and merely extended to new events through learning. Vernon (1970) indicates that infants have to learn by experience that objects and events in the environment are permanent even though they may change their appearance from time to time as their distance and orientation changes. Clearly, the capacity to recognize identity, indeed the expectation of the continuity of objects and events in the environment, is well developed in the perception of adults.

Recognition of object identity is central to Piaget's formulations. According to Elkind (1969), Piaget's conception of concept emphasizes the variability that occurs within things--changes in state, form, and appearance which can occur to any entity.

Elkind pointed out further that American psychologists have tended to ignore this within-instance variability of concepts and have emphasized the discriminative response aspect of concept attainment by which positive instances are cognized and discriminated from noninstances. Elkind summarized the two points of view thus:

> From the discriminative response point of view, the major function of the concept is the recognition or classification of examples. The Piagetian conception, however, assumes that a major function of the concept is the discrimination between the apparent and the real. This discrimination, in turn, can be reduced to the differentiation of between- and within-things types of variability. Here again, a comprehensive conception of a concept must include both functions because, in fact, every concept does serve both purposes [1969, p. 187].

The present model proposes that a concept is attained at the identity level temporally before it is attained at the classifactory level. Stated differently, the individual must be able to cognize various forms of the same objects as equivalent before he is able to generalize that two or more different objects belong to the same class.

Classificatory Level

The lowest level of mastery at the classificatory level is inferred when the individual responds to at least two different instances of the same class as equivalent, even though he may not be able to describe the basis for his response. For example, when the child treats the family's toy poodle and the neighbor's miniature poodle as poodles, although he may not name the attributes of poodles, he has attained a concept at the classificatory level.

While generalizing that at least two different instances are equivalent in some way is the lower limit of this level of concept learning, the individual is still at the classificatory level of concept learning when he can correctly classify a larger number of instances as examples and nonexamples, but cannot accurately describe the basis for his grouping in terms of the defining attributes. Henley (cited in Deese, 1967), like many other researchers, has observed this phenomenon. Many of her subjects were able to sort cards correctly into examples and nonexamples of the concepts being learned, yet gave totally erroneous definitions of the concepts.

Formal Level

A concept at the formal level is inferred when the individual can give the name of the concept, can discriminate and name its intrinsic or societally accepted defining attributes, can accurately designate instances as belonging or not belonging to the set, and can state the basis for their inclusion or exclusion in terms of the defining attributes. For example, the maturing child demonstrates a concept of dog at the formal level if, when shown dogs, foxes, and wolves of various sizes and colors, he properly designates the dogs as such, calls them "dogs," and names the attributes that differentiate the dogs from the foxes and wolves. The distinctive aspect of this level of concept mastery is the learner's ability to specify and name the defining attributes and to differentiate among newly encountered instances and noninstances on the basis of the presence or absence of the defining attributes.

As noted in Figure 1, the labels for the concept and the defining attributes may be learned at any of the three lower levels, but are not essential at those levels. Similarly, the discrimination of the defining attributes may occur prior to the formal level, but this is not essential. Thus, discrimination of things on their global and diffuse stimulus properties which is essential at the concrete level changes to discrimination of more specific and abstract properties at the identity and classificatory levels. However, at the formal level the individual must be able to discriminate and label all the defining attributes of the concept.

The operations involved in the learning of concepts at the formal level are also shown in Figure 1. The first operation given at the formal level is that of discriminating the attributes. As already noted, for some concepts with obvious attributes such as color and form, the discriminations may have occurred at earlier levels. However, making the discriminations and having the labels for the attributes are both essential at the formal level. This is true whether the individual infers the concept by hypothesizing and evaluating relevant attributes or cognizing the attributes common to positive instances, as shown in Figure 1.

Individuals differ in their ability to analyze stimulus configurations into abstract dimensions or attributes. There is evidence (Gibson, 1969) that this ability develops with age. Retarded children may have difficulty with simple concept learning tasks because of the difficulty in learning to select out and attend to specific dimensions (Zeaman & House, 1963). Even among children of adequate intelligence, there are those who characteristically analyze the stimulus field and apply labels to attributes while others tend to categorize on the basis of a relatively undifferentiated stimulus (Kagan, Moss & Sigel, 1963).

Orienting instructions may be given to make explicit the attributes of the stimuli (Klausmeier & Meinke, 1968). These instructions facilitate the learning of concepts at the formal level by assuring that the learner knows all of the attributes that may be relevant to the concept.

Having discriminated and named the attributes, an individual may infer the formal level of a concept in either of the two ways shown in Figure 1. One way involves formulating and evaluating hypotheses and the other involves cognizing the common attributes in positive instances. Which strategy a learner uses depends on the instructions he has been given, his age, and the kind of concept instances he experiences.

Levine (1963) defined a hypothesis as the subject's prediction of the correct basis for responding. In the hypothesis-testing approach, the learner guesses a possible defining attribute or combination of attributes. He then compares this guess with verified examples and nonexamples of the concept to see whether it is compatible with them. If they are not compatible, he makes another guess and evaluates it against further examples and nonexamples. Eventually, he combines the information he has obtained from testing his hypotheses so as to infer all the defining attributes and thereby the concept.

Essential to the hypothesis-testing approach are the operations of remembering and evaluating hypotheses. There is support (Levine, 1963; Williams, 1971) for the idea that the subject formulates and remembers a population of hypotheses, remembers the hypotheses that were rejected, and also remembers the last one accepted as correct. In connection with evaluating hypotheses, Bruner, Goodnow and Austin (1956) indicated that an individual determines whether or not his hypothesized concept is valid by recourse to an ultimate criterion, test by consistency, test by consensus, or test by affective congruence. Inherent in all four procedures is establishing a criterion for judging the correctness of a hypothesis. In the present model, the validity of an individual's concept may be assessed in terms of how nearly it corresponds to expert agreement concerning the concept. Our experiments have shown that instructions to subjects which include a decision rule for evaluating hypotheses facilitate concept attainment.

The operations involved in the hypothesis-testing approach to inferring concepts appear to characterize indivuduals who cognize the information available to them in laboratory and classroom settings from both positive and negative instances. These individuals apparently reason like this: Instance 1 had land surrounded by water. It is a member of the class. Instance 2 has land but is not surrounded by water. It is not a member of the class. Therefore, lands surrounded by water belong to the class and lands not surrounded by water do not. Surrounded by water is a defining attribute of the concept. This individual has attained a partial and possibly complete definition of the concept based on experiences with only one positive and one negative instance.

A second way of inferring the concept is by noting the commonalities in examples of the concept. The commonality approach is used more often than the hypothesizing approach by children, either because they are incapable of carrying out the hypothesizing and evaluating operations or because they for other reasons pursue the commonality strategy (Tagatz, 1967). In this connection the commonality approach is entirely appropriate for use when only positive instances of the concept are available. Thus, it is probably employed in situations where the individual is given only positive instances or verbal descriptions of positive instances.

Our model is considered appropriate for learning concepts at the formal level by a didactic method of information presentation as well as an inductive one. We agree with Ausubel (1966) that many concepts are attained at the classificatory and formal levels by upper elementary, high school, and college students through being given the names of concepts, verbal definitions, and verbal examples, but no actual instances of the concepts. Ausubel has designated this kind of learning "concept assimilation," an example of meaningful reception learning, to contrast it with "concept formulation," an example of meaningful discovery learning.

We should consider briefly what takes place when the learner is given the concept name, its defining attributes, and a verbal description of an instance or two, as is frequently done in classroom settings. The individual may attain a concept at a low level of mastery through this brief instructional sequence. However, his main task thereafter is to generalize properly to newly encountered positive instances and to discriminate noninstances. The basic operations entailed in this identification of newly encountered instances are hypothesizing whether the instance does or does not belong to the concept and evaluating the hypothesis in terms of the defining attributes given in the definition. Prerequisite to these two operations are discriminating the attributes of the concept and knowing their labels.

Acquiring Appropriate Labels

The importance of language in concept learning is widely acknowledged by American (Bruner, 1964) and Russian (Vygotsky, 1962) psychologists. Having the labels of concepts enables the individual to think in symbols rather than in images and to attain other concepts through language experiences in the absence of perceptible instances. Carroll (1964), as noted earlier, has outlined the close relationships among concepts, meanings, and words. However, the purpose here is not to deal with the relationships between language and concept learning, which will be dealt with in a later chapter, but to show at what points labels may be learned and associated with the various levels of concepts.

Figure 1 indicates that a concept label may be associated with an instance of the concept at any of the four levels--concrete, identity, classificatory, or formal. For example, a child might manifest a sequence like this: The young child first encounters a dog. The child's mother points to the dog and says "dog." The child then says "dog," and associates the name with his concrete concept of the dog. Next, the child develops the concept of the same dog at the identity level through experiencing it in different locations and situations. His mother repeats the name at various times in the presence of the dog; the child says the word repeatedly. The word "dog" now comes to represent the child's concept of the dog at the identity level. Subsequently, the child encounters other dogs and observes that they, too, are called "dogs." He generalizes the different dogs as equivalent in some way and associates the name "dog" with whatever similarities he has noted. The word thus comes to represent his class of things called "dogs." At the formal level, the more mature child discriminates and learns the societally accepted attributes of the class of things called "dogs" and also learns the names of the attributes. Now the child's concept of dog approaches or becomes identical to the societally accepted definition of the word "dog." As Carroll (1964) pointed out, the concepts held by individuals and the meanings of the words representing the concepts are the same for mature individuals who share similar cultural experiences and the same language.

In connection with language and concept attainment, we recognize that deaf individuals and others who lack normal speech development may attain concepts at the formal level. By our definition, the individual must know the defining attributes of the concept and must be able to communicate this knowledge. Verbalizing is normally used in this kind of communication. Other types of symbolic communication, for example, sign language, may also be employed. Speech, per se, is not necessary for the attainment of concepts, but some means for symbolizing and communicating the concept in the absence of examples is necessary at the formal level.

Concept Extension and Utilization

The individual who has formed a concept may extend and use it as shown in Figure 1. As noted earlier, a concept attained only to the concrete or identity level may be used in solving simple perceptually based problems. Concepts learned at the classificatory and formal levels can be used in generalizing to new instances, cognizing supraordinate-subordinate relations, cognizing cause-and-effect and other relations among concepts, and in solving problems.

Ausubel (1963) and Gagné (1970) have theorized concerning the use and extension of attained concepts; however, very little empirical research has been done. In this regard Ausubel (1963) formulated the constructs of cognitive structure, advance organizer, correlative subsumption, and derivative subsumption to show how previously attained and newly encountered concepts are related, while Gagné has indicated that attained concepts are prerequisite to the learning of rules.

Generalizing to New Instances and Discriminating Noninstances

The attainment of concepts at the classificatory and formal levels reduces the need for additional learning and relearning, primarily because the individual is able to generalize to new instances of a concept and to discriminate noninstances. Having a concept also provides the individual with expectations which help him deal effectively with new instances of it. Once he identifies a plant as poison ivy, he may treat it gingerly. One test of concept attainment in our experiments is the individual's ability to properly categorize instances not previously encountered as instances or noninstances of the particular concept. We find that both school children and college-age students generalize to new instances readily. Furthermore, the use of instances and noninstances in instructional materials to teach concepts can be manipulated so that errors of overgeneralization and undergeneralization can be reduced (Feldman, 1972; Swanson, 1972).

Not only does having a concept enable the learner to identify new instances and act appropriately toward them, but direct and verbal experiences with the new instances possibly increase the validity and power of the concept for the individual. For example, the Canadian visiting Kenya during January, when it is summer there, may attain more valid and powerful concepts of flower and plant. Similarly, by being told that a whale is a mammal, an individual comes to realize that mammals can live in the water as well as on land. Hence, his concept of mammal has greater validity.

Cognizing Supraordinate-Subordinate Relationships

Besides generalizing to new instances, individuals can also use their concepts attained at the formal level, and possibly at the classificatory level, in cognizing coordinate, supraordinate, and subordinate relationships among classes of things. The lowest level of cognizing these relationships is inferred when the individual, according to verbal instructions, puts instances of hierarchically arranged concepts in their proper groups. For example, an individual upon request puts all instances of red and blue equilateral triangles and of right triangles in a grouping of triangles, and all instances of triangles and of rectangles in a grouping of polygons. Furthermore, he justifies each group formed on the basis of the defining attributes of the group. For example, he states that equilateral triangles include all the triangles that have three equal sides, triangles include all the polygons that have three sides, and polygons include all the closed, planar figures that have three or more sides. More precise terminology might be required such as "an equilateral triangle is a simple, plane, closed figure with three sides of equal length."

Possible higher levels of attaining the supraordinate-coordinate-subordinate relationships include what Kofsky (1966) designated as the "whole is the sum of the parts" and "some but not all." Again, merely being able to group a few instances properly according to verbal instructions is not a sufficient test of cognizing the sets of relationships; an adequate justification for the actions is required. According to Kofsky (1966), knowledge concerning supraordinate-subordinate relationships increases with age.

The understanding of supraordinate-subordinate relationships increases the validity and usability of the individual's concepts. For example, knowing the attributes of acid and also that vinegar is an acid leads to the inference that vinegar has the attributes of all acids, as well as the attributes peculiar to vinegar. Thus, all of the things known about acids--for example, how they react with bases--are true for vinegar also. In this way, learning that acid is a concept supraordinate to vinegar increases the validity and usability of the concept of vinegar for the individual.

Cognizing Other Relationships

In the model, statements of relations between or among concepts involving cause and effect, correlation, probability, and other lawful relations such as contained in axioms are treated as different from relations among supraordinate and subordinate concepts. These first three kinds of relationships are referred to by Marx (1970) as laws and by Gagné (1966, 1970) as principles or rules. Mathematicians particularly specify established lawful relations of "givens" in axiomatic statements.

Bruner, Goodnow and Austin (1956) have pointed out that understanding lawful relationships between or among concepts permits the relating of classes of things instead of individual things. In this connection, Gagné (1970) has cited the example of the rule "round things roll," and indicated that this rule enables the individual to predict what will happen to all round things under certain circumstances. Or, consider the more complex relationship: "When two substances at different temperatures come into contact, the temperatures of the substances tend to equalize." This relationship permits us to infer what will happen in such diverse situations as putting ice cubes in warm soda pop or being lost in a snowstorm.

In all cases, being able to understand and use a lawful relationship depends on knowing the concepts that are related. Only then can the principle or axiom be understood and possibly applied to the appropriate phenomena.

Using Concepts in Problem-Solving Situations

Woodruff (1967) discussed the role of concepts in higher-level mental activities, including problem-solving. Also, Gagné (1970) indicated that one way in which concepts are called into play in solving problems is by the application of principles to the problem-solving situations. For example, principles underlying the concepts of pressure, volume, gravity, and distance can be utilized to determine the height of a mountain using a barometer.

Additional Features of the CLD Model

The CLD model is more heavily oriented toward learning than toward deve pment in that it implies that all the concepts held by any individual are learned; they do not emerge simply with maturation. In this context it is similar to four theories of concept learning generated by American experimental psychologists and reviewed by Bourne, Ekstrand, and Dominowski (1971): theory of associations (Bourne & Restle, 1959), theory of hypotheses (Levine, 1966; Trabasso & Bower, 1968), theory of mediation (Osgood, 1953), and theory of information processing (Hunt, 1962). Also, in agreement with these theories, the model specifies that the attainment of concepts is potentially explainable in terms of principles of learning. Despite some differences in terminology, the CLD model, like Hunt's, represents an information-processing approach to learning. The CLD model differs from the four theories just mentioned in that it describes different levels in the attainment of the same concept and specifies the operations essential to attaining concepts at the successively higher levels. While some of the operations are postulated to be common to more than one level, these operations at the successively higher levels are carried out on more highly differentiated and abstract properties of actual concept instances or on verbal descriptions of instances and attributes.

The CLD model is similar to Gagné's (1970) cumulative learning model in that both provide a framework for studying the internal and external conditions of learning. It also differs in two regards. Whereas Gagné describes seven forms of learning, ranging from the simplest learning through rule learning and problem solving, in the CLD model only one form of learning, concept learning, is analyzed according to its several constituent cognitive behaviors at each of four levels. Gagné also postulated a linear vertical learning hierarchy extending from signal learning through problem solving. The CLD model, as shown in Figure 1, indicates that a concept when learned at the classificatory or the formal level may be used in cognizing supraordinate-subordinate relations among the concept and other attained concepts, in understanding relations among concepts such as incorporated in principles and laws, and in problem solving. Thus, the CLD model departs from the straight linear learning hierarchy postulated by Gagné.

Possibly different from the preceding learning theories and more in agreement with Piaget (1970), the CLD model presumes that the new operations at each successive level involve qualitative changes in operating on instances and attributes of concepts, not merely additions to or modification of prior operations. Further, the operations that continue from one level to the next are carried out on more highly differentiated and abstracted concept attributes. While the model does not postulate a stage concept associated with age levels as does Piaget, qualitative differences in thinking of the kinds pointed to by Kagan (1966) and Bruner, Olver, Greenfield, et al. (1966) are recognized. Also, Bruner's (1964) conceptualization of enactive, iconic, and symbolic representation is accepted as a satisfactory global explanation of how experiences are represented and stored.

The roles of language and directed learning experiences are recognized as of central importance in attaining concepts at the classificatory and formal levels. The cross-cultural studies of Bruner, Olver, Greenfield, et al. (1966) support the directed-experiences point of view (cf. Goodnow, 1969). Also, Bruner's (1964) intermediate position that specifies how language facilitates thinking, rather than being essential to thinking (Luria, 1961) or being dependent on thought (Inhelder & Piaget, 1964), appears valid for the present model. Accepting directed experience as critical in concept attainment deemphasizes a maturational readiness viewpoint, such as that expressed by Gesell (1928, 1945). While it is accepted that certain cognitive operations emerge with educational experience, this conception does not espouse a behaviorist-environmentalist point of view regarding learning to the extent that either Gagné (1970) or Staats (1971) does.

II
Purposes and Methods of the Study

This chapter is intended to provide some perspective regarding the role of the present study in a longitudinal assessment program and to delimit the specific purposes of the present study. The plan of the longitudinal research is briefly outlined. Then the purposes of the present study, the specific predictions which are evaluated, and the research design are described in detail.

Overview of the Longitudinal Study of Children's Conceptual Development

The primary objective of the longitudinal research is to chart the conceptual development of children from about age 4 to 18. This goal will be accomplished primarily from analyses of longitudinal data that are collected once each year over a period of several years. The rationale and strategy for this programmatic research on children's conceptual learning and development from preschool to the high school years have been outlined in an earlier paper by Hooper and Klausmeier (1973). The theoretical framework for the study reported in this paper is the CLD model which has been described in Chapter I.

The data collected annually as part of the longitudinal study may be treated as a cross-sectional assessment of children's conceptual learning. The present report, based on the first-year assessment of the longitudinal study, is the first such reporting of cross-sectional findings from the larger program. Performances of children on two CLD assessment batteries are compared over four age groups in order to obtain information about the course of children's conceptual development. This information is evaluated in terms of various predictions that are derived from the CLD model.

The Strategy for the Longitudinal Assessment

The plan of the longitudinal investigation is to study a sample of children from four age groups at four consecutive times during slightly more than three calendar years. The grade groups at the time of first-year assessment in 1973 were kindergarten, third, sixth, and ninth. Each group will be tested in the spring of 1974, 1975, and 1976. Thus, over three calendar years data will be gathered that include the entire age range of 5 to 18 years with 100 percent overlap of the first and final assessments for the four age groups.

Essential control groups are incorporated in the longitudinal design to permit an evaluation of possible confounding effects commonly associated with long-term repeated-measurement designs. Among these methodological concerns is the possible role of repeated testing effects. In the present instance a variation of the Campbell and Stanley (1963) posttest-only control group design will be employed to evaluate the role of repeated test administrations. Since the design to be used does not provide for the disentanglement of the effects of repeated testing and selective drop-out, special attention will be directed toward the possible changing characteristics of the surviving core longitudinal samples.

Sampling Design of the Longitudinal Study

Selective sampling problems and the associated constraints upon external validity are difficult to avoid in any investigation of the present type. While generalization of the resultant developmental norms will obviously be confined to similar age-grade levels and demographic classifications, attempts will be made to ensure representative sampling among classes within two different school populations. Cohort biases are not expected to be a major concern but will be controlled for in one school district.

The target field locations for the longitudinal study are Watertown, Wisconsin and Beloit, Wisconsin. The public schools of Watertown provide the locale for the initial tryout and validation of the CLD model assessment batteries related to the concepts of <u>equilateral triangle</u>, <u>cutting tool</u>, <u>noun</u> and <u>tree</u>. At the same time, the four age groups that participate in these studies will also be followed for each of the successive years.

The Watertown and Beloit studies comprise a simultaneous replication of the longitudinal study. Beloit has been designated as the major source of longitudinal data, however, because its population better reflects the distribution of socioeconomic levels in the U.S. The overall sampling design for the research in Beloit is shown in Table 1.

TABLE 1

SAMPLING DESIGN FOR THE CLD TESTS

	Time of Measurement			
Cohort	1973	1974	1975	1976
1967	6* (N=100) →	7 →	8 →	9
1968	[Kindergarten]	6 —40→	7** →	8** (Cohort effect group)
1967		7		
1969			6** →	7**
1967			8**	
1970				6**
1967				9 (Test effect group)
1964	9 (N=100) →	10 →	11 →	12
1965	[Third Grade]	9 →	10* →	11**
1964		10		
1966			9** →	10**
1964			11**	
1967				9**
1964				12
1961	12 (N=100) →	13 →	14 →	15
1962	[Sixth Grade]	12 →	13** →	14**
1961		13		
1963			12** →	13**
1961			14**	
1964				12**
1961				15
1958	15 (N=100) →	16 →	17 →	18
1959	[Ninth Grade]	15 →	16** →	17**
1958		16		
1960			15** →	16**
1958			17**	
1961				15**
1958				18**

*Table entries are approximate mean ages.

**These groups will not be continued if cohort and practice effects are not found after the first year. If effects are found, decisions about continuing will be made after data are analyzed.

Objectives of the Longitudinal Study

The major data analyses will utilize the longitudinal and cross-sectional assessments under the following general guidelines. The cross-sectional data collections will permit the specification of relative task difficulties (e.g., group means comparison, intercorrelations, and pass/fail contingency analyses) and the suggestion of the probable order of acquisition of these concept domains. The longitudinal data collections will enable us to (1) specify the order of attainment of the various levels and uses of concepts by children in the various grade groups of the two school districts; (2) describe the form of the developmental curve for each level of attainment, concept use, and vocabulary acquisition, from first partial attainment through final full mastery; and (3) relate the mastery of each level to the mastery of each use, and to vocabulary development.

Thus, the primary objectives of the longitudinal study are (1) to chart the course of children's attainment of selected concepts in various subject fields during their school years, (2) to chart the course of children's uses of the same concepts during their school years, (3) to chart the course of children's development of crucial terminology related to the selected concepts, and (4) to relate the three preceding areas of development. The general propositions and more specific predictions pertaining to these matters that can be tested in a cross-sectional study are treated later in this chapter.

Other goals of the longitudinal study, cross-sectional studies, and various controlled experiments are as follows: (1) to determine more explicitly the internal conditions of learning associated with children's mastery of the various levels of concept attainment and their uses, (2) to determine more explicitly the external conditions of learning that facilitate children's attainment and use of concepts in school settings, (3) to relate children's performances on the four CLD batteries dealing with equilateral triangle, cutting tool, noun, and tree, (4) to relate children's levels of conceptual development as assessed by CLD model batteries to their school achievement in various subject matters, and (5) to validate the CLD model in terms of its robustness in providing a framework for research in concept learning, concept development, and related instruction.

Design of the Present First-Year Cross-Sectional Study

The data collected each year as part of the longitudinal study may provide useful information about patterns of conceptual learning and development. Therefore the present study serves both as the initial data collection in the longitudinal program and also as a cross-sectional study of conceptual development.

Purposes of the Study

The CLD model embodies three major propositions. Related to each proposition there are several specific predictions. These major propositions and the related predictions concern hypothesized patterns of children's conceptual learning and development. The purpose of the present study is to test these predictions, thereby clarifying presumed sequencing in conceptual development.

A. Many concepts are attained in an invariant sequence according to four successive levels: concrete, identity, classificatory, and formal. Each level is presumed to be increasingly difficult to attain because of the new operations which are essential to attaining the particular level. It is further presumed that to attain a concept at any particular level an individual must be capable of all of the operations at that level and at the prior level and must also have attained the particular concept at the preceding level. These, then, are the prerequisite internal conditions for attaining each consecutive level.

The major proposition also indicates that many, but not necessarily all, concepts are attained in an invariant sequence. Three conditions are essential for concepts to be attained according to the invariant sequence. First, many actual instances or readily constructed instances are present in the immediate environment that children experience. Second, the child must have experiences with the actual instances or the representations thereof starting early in childhood. Finally, the child must be developing normally, free of severe handicaps of speech, language development, brain injury, etc.

The preceding proposition concerning the invariant sequence can be evaluated definitively only through longitudinal study. However, there are a number of predictions which follow from the proposition that can be tested in a cross-sectional study in which children of various age levels or grade groups participate. The three specific predictions tested in the present cross-sectional study are as follows:

1. All children of all grade groups will conform to five acceptable patterns of mastery of the four concept levels. These acceptable patterns are to (a) fail all four levels (FFFF), (b) pass the concrete and fail the next three levels (PFFF), (c) pass the concrete and identity levels but fail the next two levels (PPFF), (d) pass the first three levels but fail the formal level (PPPF), and finally, (e) pass all four levels (PPPP).
2. The number and proportion of children within a single grade group who pass each successive level of concept attainment will decrease. For example, fewer third-grade children will pass the classificatory level than pass the identity level.
3. The number and proportion of children of successively higher grade groups mastering each concept level will increase. For example, more sixth grade children than third grade children will pass each of the four levels.

B. Concepts attained to various levels may be used in (1) cognizing supraordinate-subordinate relationships in a hierarchy where the attained concept is an element of the hierarchy, (2) in understanding principles that state a relationship between the attained concept and one or more other concepts, and (3) in solving problems that require use of the particular concept.

The specific predictions which follow from the preceding proposition and which were tested in the present study are as follows:

4. A higher proportion of children who attain a concept at the formal level, in comparison with those who attain at the classificatory level, will also master each of the three concept uses.
5. Children who attain a concept to only the concrete and/or identity level will be able to use that concept only in understanding simple perceptual problems.
6. The number and proportion of children of successively higher grade groups who master each concept use will increase.

C. Having the labels of the concept and its attributes (1) facilitates attainment of the concept at the classificatory level and possibly the other levels, (2) is requisite for attaining the concept at the formal level, and (3) facilitates mastery of the three uses of the concept. This proposition emphasizes the importance of language in attaining concepts at the classificatory and the formal levels and also in being able to use the concept in various ways.

The two specific predictions related to this proposition which were tested in the present study may be stated as follows:

7. Vocabulary scores and scores based on attainment of the four levels and the three uses will correlate positively within grade groups. The correlations must be positive to support the prediction; however, within some grade groups they may be low due to very little variability in either mastery of the vocabulary or in attainment of the various levels and uses.
8. Vocabulary scores and scores based on the levels and uses will correlate positively for the combined grade groups; correlations should be higher than those obtained within grade groups. These correlations should be of greater magnitude since large variations among the children both in vocabulary attainment and in attainment of the levels and uses is expected when all the children of the combined grade groups are included.

Assessment Batteries Used

In addition to the usual criteria of reliability, objectivity, and usability, several other criteria guided development of the batteries. First, the materials and instructions had to permit assessment of subjects of preschool through high school age. It was presumed that not all subjects of preschool age would attain a given concept at the concrete level and that not all high school subjects would attain it at the formal level. Second, to test for attainment at the concrete, identity, and classificatory levels the particular concept selected had to have perceptible instances or representations thereof. Third, the concept had to be definable by publicly accepted attributes in order to test attainment at the formal level. (It should be noted that many concepts are definable in terms of attributes even though this method of definition is often not used, even in unabridged dictionaries.)

Fourth, the concept selected for a battery should be relatable to the subject matter which pupils encounter in school. This is in keeping with the supposition that directed experience, including instruction in school, is a powerful determinant of the particular concepts attained by individuals and also of their level of attainment and use. Further, since must instruction in school deals with concepts, the CLD model should be applicable to the design of instruction, and the subtests, when fully validated, should be usable in assessing the level of conceptual development in school-age children. Fifth, the particular concept had to be part of a taxonomy in order to test its use in cognizing supraordinate-subordinate relationships. Finally, the concept had to be usable in cognizing principles and in problem solving. (A concept may be usable in solving simple problems that can be solved on a perceptible basis without being used first in understanding a principle, or it may be used first in understanding a principle and then in solving more complex problems.)

In the present study, assessment batteries were developed for each of two concepts: equilateral triangle (Klausmeier, Ingison, Sipple, & Katzenmeyer, 1973) from the field of mathematics and cutting tool (Klausmeier, Bernard, Katzenmeyer, & Sipple, 1973) which is a general concept probably related more to science than to other curriculum areas.

To develop the tests of concept attainment and utilization, the behaviors involved in attaining the concept were analyzed and then test items and administrative procedures to assess the behaviors were developed. For each battery, a subtest was developed to assess each of the four levels of concept attainment. Each subtest was constructed specifically to assess the particular operations involved in attaining a concept at each of the four levels. A subtest was also developed to ascertain the extent to which a child could apply the concept in each of the three uses that have been described. Thus, a total of 14 subtests was developed, seven for each of the two concepts. All subtests in each of the batteries were designed as paper-and-pencil tasks that could be group administered.

For each of the batteries, items within the concrete, identity, and classificatory levels were constructed to be more difficult as nonexamples (1) increased in number and (2) shared more relevant and/or irrelevant attributes with the target examples. Specific information regarding the exact number of items used in each subtest of a battery is available in Tables 3 and 12 which are included in the two chapters dealing with results of the assessment of equilateral triangle and cutting tool. All test items went through expert review and empirical validation while under development.

Participating Children

Four hundred school children from Beloit, Wisconsin participated in each of the two assessment series. All subjects received both batteries. One hundred children at each of four grade levels--kindergarten, third, sixth, and ninth grade--took part in each of the assessment series. Children in the three lower grades were enrolled in four different elementary schools. The ninth grade students were enrolled in a high school. These schools and classrooms were judged to be typical of the particular school system and also of a large number of classrooms in small towns in Wisconsin. Each of the subject populations is described in greater detail in the chapters presenting results.

Data Collection

The appropriate subtests of the battery were administered to children in intact classrooms. Small groups of additional children at each grade were used as necessary to obtain the total number required by the research design. The kindergarten children were always tested in small groups of about five to eight in order to reduce distractibility and, in general, to enable the test administrators to supervise the test-taking situation more closely. Each of the batteries was administered at a different time within a three-month period. Two test administrators, one male and one female, were responsible for giving the batteries in both assessment studies. The classroom teacher usually remained in the classroom during the test administration to assist in monitoring the test situation. The same administrators were responsible for scoring the tests and for coding the test information for subsequent data analyses.

Treatment of the Data

On each subtest of an assessment battery a subject was scored as having either passed or failed; that is, results of each assessment battery were treated as dichotomous data. Criteria set for each subtest determined passing, or attainment of a subtest. Specific criteria for attainment of each subtest in each of the assessment batteries will be explained in Chapters 3 and 4, which present, respectively, results of the assessment of equilateral triangle and cutting tool.

In general, data were quantified by computing frequencies and proportions of subjects at each grade group who attained each concept level and each uses subtest. In addition, certain post hoc statistical tests were used where appropriate to obtain more specific information about differences in frequencies and proportions. The predicted relationships between vocabulary and performance on the subtests dealing with the concept levels and uses were evaluated by computing correlation coefficients. Each of the specific predictions outlined in this chapter is evaluated in terms of these descriptive analyses.

III
Results of CLD Assessment Series I: Equilateral Triangle

Overview

A brief description of the child population precedes a report of the specific criteria for full attainment of each subtest of the battery. The major portion of the chapter is devoted to results of the assessment as they bear on each of the CLD predictions.

Child Population

Table 2 presents a summary description, according to age and sex, of the 400 children who participated in the first assessment series: equilateral triangle. Fifty males and 50 females from each of four grade groups took part in the study. The age range of children within each grade varied from 13 to 18 months. The smallest range, 13 months, occurred in the kindergarten group and the largest, 18 months, in the sixth grade group.

Criteria for Full Attainment

It was reported earlier that one test was used for each level of concept attainment and one test for each concept use. For each of the levels and uses subtests specific criteria determined full attainment. In general, a criterion required that all items of a subtest, except one, had to be passed. One error was permitted in order to make some allowances for error of measurement. These criteria are especially important since passing the four levels of concept attainment in consecutive order is considered critical for delineating the course of children's conceptual development as presumed by the CLD model.

Table 3 summarizes information concerning number of items and criteria for attainment on each subtest of the battery. There are two exceptions to the criteria convention; the classificatory subtest consisted of three items,

TABLE 2

NUMBER OF MALES AND FEMALES, MEAN AGE, AND AGE RANGE AT EACH GRADE GROUP

Grade	Males	Females	Mean Age (in years and months)	Age Range (in years and months)
K	50	50	5-10	5-3 to 6-4
3rd	50	50	8-11	8-3 to 9-8
6th	50	50	11-10	11-2 to 12-8
9th	50	50	14- 9	14-2 to 15-7

all of which were required for attainment, and the labels test consisted of seven items, five of which were required for attainment. Number of items comprising each of the remaining subtests, as well as criteria for passing, can be reviewed in Table 3. (Note that the model calls for two other kinds of items to assess the formal level. At the time of this administration, however, these items were not yet developed.)

Proportion of Each Grade Group Conforming to the Predicted Invariant Sequence

Basic to the CLD model is the postulate that each successive level of concept attainment requires the use of one or more new cognitive operations. Each subtest will be more difficult than the previous one because it demands an additional cognitive operation. The CLD model, then, limits the number of acceptable patterns of success and failure for the concept levels to five. These are: to fail all four levels (FFFF), to pass the concrete level and fail the next three (PFFF), to pass both concrete and identity and to fail the last two (PPFF), to pass the first three levels and fail formal (PPPF), and finally to pass all four levels (PPPP).

The first five rows of Table 4 show the number and proportion of each grade group that attained the successive levels according to each of the five patterns predicted by the model. Three hundred and sixty of the 400 subjects (90 percent), demonstrated attainment of the levels consistent with the predicted invariant sequence. More specifically, the following numbers conformed to each of the five predicted patterns: 4 FFFF, 7 PFFF, 65 PPFF, 151 PPPF, and 133 PPPP. The rank order of grade groups conforming to acceptable patterns are ninth, sixth, third, and kindergarten.

Eleven patterns of performance are not compatible with the model. The bottom of Table 4 shows the number and proportion of children who displayed nonconforming patterns. Ten percent (40 children) of the total subject population did not conform and are distributed over six of the eleven unacceptable patterns. Inspection of Table 4 also reveals the contribution of the four grade groups to nonconforming patterns. Thirty-four of the 40 deviations originated in the two lowest grade groups, whereas only five sixth graders and one ninth grader showed non-conforming patterns. Deviating subjects from the two lower grade groups were also distributed over a number of the non-conforming patterns, whereas all six deviating children from the highest grade groups displayed the PPFP pattern; that is, contrary to predictions, they passed the formal level after failing classificatory.

The fact that 90 percent of our 400 subjects conformed to the predicted invariant sequence of attainment is highly supportive of the major proposition of the CLD model. At the same time, analysis of the protocols of nonconforming children may explain why

TABLE 3

NUMBER OF ITEMS AND CRITERIA DEFINING FULL ATTAINMENT
FOR EACH CONCEPT LEVEL AND USE

Subtest	Number of Items	Criteria for Full Attainment
1. Concrete	8	7 correct
2. Identity	8	7 correct
3. Classificatory	3	3 correct
4. Formal		
a. Discriminating Attributes	3	2 correct
b. Labels	7	5 correct
5. Principle	5 pairs	4 correct
6. Problem Solving	5	4 correct
7. Supraordinate-Subordinate	4 pairs	3 correct

TABLE 4

NUMBER AND PROPORTION OF FOUR GRADE GROUPS CONFORMING AND NOT CONFORMING TO PREDICTED SEQUENCE OF ATTAINMENT

	K (n=100)	3rd (n=100)	6th (n=100)	9th (n=100)	All Grades (N=400)
FFFF	4 .04	0 .00	0 .00	0 .00	4 .01
PFFF	5 .05	2 .02	0 .00	0 .00	7 .02
PPFF	41 .41	18 .18	5 .05	1 .01	65 .16
PPPF	30 .30	54 .54	49 .49	18 .18	151 .38
PPPP	0 .00	12 .12	41 .41	80 .80	133 .33
Subtotal Conforming	80 .80	86 .86	95 .95	99 .99	360 .90
FFFP	0 .00	0 .00	0 .00	0 .00	0 .00
FFPF	4 .04	0 .00	0 .00	0 .00	4 .01
FFPP	0 .00	0 .00	0 .00	0 .00	0 .00
FPFF	8 .08	0 .00	0 .00	0 .00	8 .02
FPFP	0 .00	0 .00	0 .00	0 .00	0 .00
FPPF	2 .02	6 .06	0 .00	0 .00	8 .02
FPPP	0 .00	0 .00	0 .00	0 .00	0 .00
PFFP	0 .00	0 .00	0 .00	0 .00	0 .00
PFPF	6 .06	5 .05	0 .00	0 .00	11 .03
PFPP	0 .00	1 .01	0 .00	0 .00	1 .00
PPFP	0 .00	2 .02	5 .05	1 .01	8 .02
Subtotal Not Conforming	20 .20	14 .14	5 .05	1 .01	40 .10

their performance deviated from the prediction.

Table 5 presents frequencies of subjects according to each pattern of exception and number of items correct at each concept level for which attainment criterion was not met. Twenty children failed the concrete level but went on to attain at least one higher level. Of these, 18 fell just short of criterion (7 items correct) for attainment at the concrete level, and 2 fell far short of criterion. Sixteen subjects failed the identity subtest but went on to pass a higher level. Thirteen of these children barely missed or came close to criterion (7 items required); three fell farther short of criterion. All eight subjects who did not attain the classificatory level but who passed formal barely missed criterion for attainment at the classificatory level. Examination of most of these protocols, then, reveals that attainment of a level that should have been passed, according to the model, was just barely missed. Such deviations from the predicted sequence of attainment are probably most parsimoniously interpreted as errors of measurement associated with each subtest, or as consequences of criterion stringency, or both. Explanation of the few protocols that indicate a subject attained a more difficult level after falling far short of criterion at a lower level may reasonably be attributed to inattentiveness during test taking or misunderstanding of directions.

Predicted Sequence of Concept Attainment and Difficulty of the Levels

The CLD hypothesis is that the sequence of attainment is invariant because each successively higher concept level requires the use of one or more increasingly complex cognitive operations. As a consequence the items and the total subtest at each successive level are more difficult. It might be argued that the invariant sequence of attainment is not a function of difficulty determined by increasingly complex cognitive operations at the successive concept levels, concrete through formal, but that it is simply a function of increasing test item difficulty unrelated to the operations. In order to ensure that the number of subjects conforming and not conforming to the predicted sequence was not merely due to increasing difficulty of the successive subtests unrelated to the more complex operations, a statistical procedure accounting for independent difficulty level was applied to data from the present assessment.

Computations were performed using the overall grade group proportions passing and

TABLE 5

FREQUENCIES OF SUBJECTS ACCORDING TO PATTERN OF EXCEPTION AND ITEMS CORRECT AT EACH CONCEPT LEVEL NOT ATTAINED

N	Pattern of Exception	Number of Items Correct on Concrete Subtest (7 required)						
		0	1	2	3	4	5	6
8	FPFF							8
8	FPPF			1			1	6
4	FFPF	1						3
		Number of Items Correct on Identity Subtest (7 required)						
		0	1	2	3	4	5	6
4	FFPF					1	1	2
11	PFPF					2	5	4
1	PFPP							1
		Number of Items Correct on Classificatory Subtest (3 required)						
		0	1	2				
8	PPFP			8				

failing each of the four subtests so that a wide range of conceptual attainment would be obtained. These computations yielded expected numbers of subjects following each of the 16 possible patterns of attainment (5 acceptable, 11 unacceptable to the model). It was noted that fewer than 5 subjects were expected to follow each of 8 of the 16 patterns. To meet the requirements of the Chi-square test, patterns were combined so that the minimum expected number of subjects in each cell would approximate five. Ten patterns and combinations of patterns resulted and were used for the test. A Chi-square goodness of fit test was used to determine whether the obtained number of subjects who followed these patterns differed significantly from the number of subjects expected to follow these patterns. The resulting Chi-square provided convincing evidence that the number of subjects following and not following acceptable patterns was not a function of increasing difficulty of test items unrelated to the operations ($X^2 = 60.68$, d.f. = 5, $p < .001$).

Proportion of Grade Groups Attaining the Four Levels

In a cross-sectional study, two related and important predictions concerning sequence of attainment of concept levels can be tested. The first prediction states that within a given grade group the percentage of children passing each successive level will decrease. At the same time, the second prediction holds that the percentage of children passing a given level will increase as a function of increasing grade group.

Information pertinent to each of these predictions is presented in Table 6 which shows the numbe and proportion of each grade group that fully attained each concept level. The row entries of Table 6 are relevant to the first prediction. At each grade group, a gradual decrement in proportion of children attaining the successive levels is apparent (although sixth and ninth graders attained the concrete and identity levels with equal proficiency). Proportions of the total subject population at each level also reflect accuracy of the prediction: 94 percent, concrete; 93 percent, identity; 77 percent, classificatory; and 36 percent, formal.

Cochran Q tests were used to discover if the proportions of subjects fully attaining the four concept levels differed significantly within each of the four grade groups. Significance of the differences among the proportions for each of the four grade groups was beyond the .001 level [Q = 161.76, kindergarten; 169.91, third grade; 131.34, sixth

TABLE 6

NUMBER AND PROPORTION OF EACH GRADE GROUP THAT FULLY MASTERED EACH LEVEL OF ATTAINMENT

Grade	Concrete	Identity	Classificatory	Formal
K (n=100)				
Number	82	81	42	0
Proportion	.82	.81	.42	.00
3rd (n=100)				
Number	94	92	78	15
Proportion	.94	.92	.78	.15
6th (n=100)				
Number	100	100	90	46
Proportion	1.00	1.00	.90	.46
9th (n=100)				
Number	100	100	98	81
Proportion	1.00	1.00	.98	.81
All Grades (n=400)				
Number	376	373	308	142
Proportion	.94	.93	.77	.36

grade; 50.11, ninth grade (d.f. = 3)]. McNemar tests were run at the .05 level of significance to determine where specific differences in attainment among the four levels occurred in each of the four grade groups. Six comparisons were possible: concrete with (1) identity, (2) classificatory, and (3) formal; identity with (4) classificatory and (5) formal; finally, classificatory with (6) formal. Five of the six comparisons differed significantly for the kindergarten grade group, the exception being concrete with identity. In each set of comparisons that did differ significantly, fewer kindergarten children passed the higher concept level. The same five comparisons proved significant for both the third grade group and for the sixth grade group. In each set of comparisons fewer third graders and fewer sixth graders passed the higher concept level. Among the ninth graders, three comparisons showed a significant difference: concrete and formal, identity and formal, and classificatory and formal. In each of these comparisons, fewer children attained the higher concept level.

Information in the columns of Table 6 bears on the second prediction--the percentage of children passing any specific level of concept attainment should increase as a function of increasing grade group. Inspection shows that the second prediction holds up, although sixth graders and ninth graders are equally proficient at both concrete and identity levels. At both the classificatory and formal levels the number of children attaining the level markedly increases in each higher grade group. For example, at the formal level no kindergarten children demonstrated mastery, whereas 15 percent of the third graders, 46 percent of the sixth graders and 81 percent of the ninth graders attained the concept.

Chi-square tests were used to find out if the proportions of individual grade groups passing each of the four levels of concept attainment differed significantly from the proportions of the combined grade groups passing each of the four levels. The difference in proportions attaining each of the levels was significant beyond the .001 level [Chi-square = 38.30, concrete; 38.57, identity; 103.67, classificatory; 168.62, formal (d.f. = 3)]. A Chi-square analog to Scheffé's theorem was performed to determine where differences between grade groups in attainment of each of the four levels were significant at the .05 level. Significant findings were as follows: at the concrete, identity, and classificatory levels, the third, sixth, and ninth grade groups each surpassed attainment of the kindergarten group. At the classificatory level also, performance of the ninth graders was superior to that of third graders. All pair-wise comparisons of grade groups were significantly different at the formal level; that is, the higher the grade group, the greater the proportion of children attaining the formal level.

The data assessing full attainment of the concept, equilateral triangle, provide strong support for both of the predictions dealing with difficulty of the concept levels.

Relationship Between Full Attainment of Various Levels and Full Attainment of the Various Uses

The CLD model predicts that individuals who have attained a concept only to the concrete or identity levels may be able to use that concept in cognizing simple perceptual relations among concepts and in solving simple problems of a perceptual kind but that they will not be able to use the concept in understanding supraordinate-subordinate relations, understanding more complex principles, or in solving more complex problems.

The first half of Table 7 presents data relevant to the prediction. None of the seven children whose highest level of attainment was concrete passed a uses subtest. Seventy-three children (primarily from kindergarten and third grade) passed the identity level as their highest level of attainment. Among these subjects there were only three instances of attainment of uses; two children were responsible for these three instances of mastery by identity level attainers. One sixth grader passed the supraordinate-subordinate subtest and one ninth grader passed both the principles and problem-solving subtests.

A second prediction of the CLD model holds that a higher proportion of subjects who attain at the formal, compared to the classificatory level, will master the three uses. The second half of Table 7 presents information relevant to a comparison of performances of children attaining at the classificatory level and those attaining at the formal level. A total of 174 subjects mastered the classificatory level as their highest level of attainment and 142 attained the formal level as their highest level. Comparisons between children performing at these two levels with attention to their mastery of the concept uses are of special interest not only to the CLD model but also to learning theorists and educators in general.

The supraordinate-subordinate subtest was passed by 3 percent of classificatory attainers, compared to 23 percent of formal attainers. The principles subtest was mastered by 5 percent of those who passed the classificatory level compared to 40 percent

TABLE 7

RELATIONSHIP BETWEEN FULL MASTERY OF VARIOUS LEVELS AND FULL MASTERY OF USES

Grade	Concrete as Highest			Identity as Highest			Classificatory But Not Formal			Formal		
	Supra-Sub	Prin.	Prob. Solv.	Supra-Sub.	Prin.	Prob. Solv.	Supra-Sub	Prin.	Prob. Solv.	Supra-Sub	Prin.	Prob. Solv.
K												
N Passing Level	5			49			42			0		
N Passing Use	0	0	0	0	0	0	0	0	0	0	0	0
Proportion	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
3rd												
N Passing Level	2			18			65			15		
N Passing Use	0	0	0	0	0	0	1	0	0	2	0	0
Proportion	.00	.00	.00	.00	.00	.00	.02	.00	.00	.13	.00	.00
6th												
N Passing Level	0			5			49			46		
N Passing Use	0	0	0	1	0	0	4	3	1	4	7	1
Proportion	.00	.00	.00	.20	.00	.00	.08	.06	.02	.09	.15	.02
9th												
N Passing Level	0			1			18			81		
N Passing Use	0	0	0	0	1	1	0	5	3	27	50	34
Proportion	.00	.00	.00	.00	1.00	1.00	.00	.28	.17	.33	.62	.42
All Grades												
N Passing Level	7			73			174			142		
N Passing Use	0	0	0	1	1	1	5	8	4	33	57	35
Proportion	.00	.00	.00	.01	.01	.01	.03	.05	.02	.23	.40	.25

of those who passed the formal level. The problem-solving subtest was mastered by 2 percent of those who passed the classificatory level compared to 25 percent of those who passed the formal level.

Chi-square tests also revealed a significant overall advantage (beyond the .001 level) for children performing at the formal level when compared to those performing at the classificatory level [Chi-square 30.66, supraordinate-subordinate; 60.46, principles; 36.19, problem-solving (d.f. = 1)].

In summary, data obtained from assessment of equilateral triangle provide strong support for both of the predictions that have been considered in this section. When a concept is attained only at the concrete or identity levels, use of the concept is limited. When a concept is attained at the formal level, compared to the classificatory level, use of the concept is greatly facilitated.

Difficulty of the Three Uses

For each grade group, Table 8 presents the number and proportion of subjects who fully mastered each of the three concept uses: supraordinate-subordinate, principles, and problem-solving. These data will be used to address the prediction that performance on the uses subtests will improve as a function of increasing grade group. Consistent with the prediction, Table 8 shows an improvement in performance in each higher grade group (although proficiency on principle and problem-solving subtests was equally absent for kindergarten and third graders). The marked improvement in mastery of each of the three concept uses between sixth and ninth grade is of special interest. The large increase in numbers of children who successfully mastered the uses subtests is attributed both to specific mathematical instruction and to the emergence of cognitive operations specified by the model.

Chi-square tests were used to ascertain the significance of the difference between the proportions of individual grade groups passing each of the three uses and the proportion of the combined grade groups passing each of the three uses. The difference in proportions of subjects attaining each of the uses was significant beyond the .001 level [Chi-square = 49.86, supraordinate-subordinate; 155.83, principles; 116.44, problem-solving (d.f. = 3)]. A Chi-square analog to Scheffé's theorem was performed between all pairs of grade groups to determine where the differences in the uses were significant at the .05 level. Results indicated that the ninth grade's mastery of each of the three concept uses was superior to that of each of the three other grade groups.

TABLE 8

NUMBER AND PROPORTION OF EACH GRADE GROUP THAT FULLY MASTERED EACH OF THE THREE CONCEPT USES

Grade	Supraordinate-Subordinate	Principle	Problem Solving
K (n=100)			
Number	0	0	0
Proportion	.00	.00	.00
3rd (n=100)			
Number	3	0	0
Proportion	.03	.00	.00
6th (n=100)			
Number	9	10	2
Proportion	.09	.10	.02
9th (n=100)			
Number	27	56	38
Proportion	.27	.56	.38
All Grades (n=400)			
Number	39	66	40
Proportion	.10	.17	.10

One additional point of interest is disclosed in Table 8. Ten percent of all subjects passed the supraordinate-subordinate subtest, 17 percent passed the principles subtests, and 10 percent passed the problem-solving subtest. These modest attainments must be viewed as specific to the items used in the subtests, the criteria established for attainment, and the nature of the concept itself. That is, it should not be assumed that these same results for mastery would hold for other concepts.

In summary, the prediction that the higher grade groups, compared to the lower, would demonstrate greater mastery of concept uses has clearly received support from these data.

Relationship Between Vocabulary Development and Attainment of Concept Levels and Uses

One of the major propositions of the CLD model is that acquisition of the labels of a concept and its attributes facilitates attainment of a concept at the classificatory level, is requisite at the formal level, and facilitates mastery of the uses of a concept. This section is addressed to the prediction that having the verbal labels for the concept of equilateral triangle and its attributes will be positively correlated with attainment of the levels and performance on the uses subtests.

In order to compute correlation coefficients, a special scaling system was derived. For each subject, a point score of one was assigned to full attainment of each concept level and each use, and a score of zero to each when mastery was not attained. The second variable for all computations was mean performance on the seven-item vocabulary test in which a score of one was again assigned to each correctly answered item. Therefore, for each individual, scores on the four concept levels could vary from 0-4; scores on the three concept uses could vary from 0-3; and scores combining levels and uses could vary from 0-7. (Combining levels and uses subtests provided a measure of overall task performance.) Similarly, the scores on the vocabulary test varied from zero, for no labels correct, to a perfect score of seven. For each subject, then, overall performances on concept level subtests, concept uses subtests, combined levels and uses subtests, and vocabulary were calculated. (Other means of scoring the levels and uses are presently under empirical study.)

This scoring system generated Table 9 which presents means and standard deviations for levels, uses, levels and uses, and vocabulary scores at each grade group. The predicted improvement in concept attainment and performance on uses with increasing grade group is, of course, demonstrated in these data based on mean scaled scores as it was in the data based on proportions. Scores on the vocabulary test also show a gradual improvement with increasing grade group.

Pearson product-moment correlations (r) were then calculated in order to discover the relationship between vocabulary comprehension and task performance. For each grade group, Table 10 presents the correlations between scores on the vocabulary test and scores on (1) concept level, (2) concept uses, and (3) combined levels and uses.

The correlations within each grade group are quite modest, especially for the kindergarten group. The very low or zero order

TABLE 9

MEANS AND STANDARD DEVIATIONS FOR COMBINED CONCEPT LEVELS, CONCEPT USES, COMBINED LEVELS AND USES, AND VOCABULARY AT EACH GRADE GROUP

Grade	N	Concept Levels: (Maximum score, 4)		Concept Uses: (Maximum score, 3)		Levels and Uses: (Maximum score, 7)		Vocabulary: (Maximum score, 7)	
		M	S.D.	M	S.D.	M	S.D.	M	S.D.
K	100	2.32	.94	.00	.00	2.32	.94	1.18	.89
3rd	100	3.43	.73	.03	.17	3.46	.77	2.85	1.69
6th	100	3.71	.54	.21	.50	3.92	.79	4.46	1.61
9th	100	3.91	.32	1.21	1.11	5.12	1.17	5.70	1.34
All Grades	400	3.34	.91	.36	.79	3.71	1.37	3.55	2.21

TABLE 10

PEARSON PRODUCT-MOMENT CORRELATIONS BETWEEN MEAN VOCABULARY SCORES AND MEAN SCORES ON CONCEPT LEVELS, CONCEPT USES, AND COMBINED LEVELS AND USES

Grade Group	N	Four Concept Levels	Three Concept Uses	Combined Levels and Uses
K	100	.09	.00	.09
3rd	100	.27**	.22*	.30**
6th	100	.33**	.17	.33**
9th	100	.17	.43**	.45**
All Grades	400	.58**	.52**	.69**

*$p < .05$
**$p < .01$

correlations for the youngest subjects reflect a limited range of performance. The range of attainment on concept levels was small, no uses subtests were passed, and little comprehension of verbal labels was demonstrated. Third, sixth, and ninth graders, by contrast, showed increasing competence with verbal labels and a wider range of performance on concept attainment and uses. The correlations for these grade groups, although not extremely high, do indicate a positive relationship between test performance and vocabulary scores. Seven of the nine correlations obtained for third, sixth, and ninth grade groups were statistically significant from zero at or beyond the .05 level.

Correlations were notably higher for the total subject population. The correlation was .58 between overall performance on concept level subtests and overall performance on the vocabulary subtest. The correlation between overall performance on three concept uses and vocabulary scores was .52 and between overall performance on combined levels and uses and vocabulary scores, .69. Each of these three correlations was statistically significant from zero at or beyond the .01 level. The predicted relation between vocabulary proficiency and concept attainment and use is clearly supported by the correlational data.

IV
Results of CLD Assessment Series II: Cutting Tool

Overview

A brief description of the child population is followed by a report of the subtests used in the assessment series and the criteria employed for full attainment. Results of the assessment, as they bear on specific predictions of the CLD model, are reported in the remainder of the chapter.

Child Population

Four hundred children participated in assessment of the concept, cutting tool. Table 11 shows the composition of the total number of subjects according to age and sex. One hundred children, fifty boys and fifty girls, from each of the four grade groups took part in the study. Age ranges varied from 13 months, for the kindergarteners, to 18 months, for the sixth graders.

Criteria for Full Attainment

Criteria were established for full attainment of each of the four concept levels and three uses. Attainment of a subtest was permitted only when the subject missed no more than one item, as shown in Table 12. For example, seven items were included to assess the concrete subtest and six of the seven were required for attainment. One

TABLE 11

NUMBER OF MALES AND FEMALES, MEAN AGE, AND AGE RANGE AT EACH GRADE GROUP

Grade	Males	Females	Mean Age (in years and months)	Age Range (in years and months)
K	50	50	6- 0	5-5 to 6- 6
3rd	50	50	9- 1	8-5 to 9-10
6th	50	50	12- 0	11-4 to 12-10
9th	50	50	14-11	14-4 to 15- 9

error was allowed, in general, in order to provide some flexibility for possible error of measurement. At the formal level a concept definition, required for attainment, was included in the subtest. Items comprising each of the remaining subtests and specific criteria for attainment are available in Table 12.

Proportion of Each Grade Group Conforming to the Predicted Invariant Sequence

In this section, descriptive data are considered in order to evaluate the prediction that the sequence of attainment of the four concept levels is invariant. Only five patterns of passing and failing the four successive levels are consistent with the CLD model (FFFF, PFFF, PPFF, PPPF, and PPPP). The number and proportion of subjects at each grade group who attained the successive levels consistent with the five acceptable patterns are presented in the first five rows of Table 13. Three hundred and forty-six subjects, or 87 percent, conformed to the model. The five acceptable patterns included the following numbers: 6 FFFF, 19 PFFF, 93 PPFF, 94 PPPF, and 143 PPPP. Rank order of grade groups conforming to predicted patterns are third, kindergarten and ninth grade tied, and sixth grade. The number and proportion of subjects who performed according to the 11 patterns of performance that are not consistent with the model are presented in the remainder of Table 13. Of the 54 children (14 percent) who deviated from the predicted invariant sequence of attainment, 40 fell into the PPFP pattern. That is, most of the nonconforming children passed the formal level after failing the classificatory level. Such a large number of nonconforming children is, of course, discrepant with the prediction. That they were concentrated in a single pattern of exception certainly requires some further attention.

The classificatory subtest contained five items, four of which were required for mastery (see Table 12). Examination of protocols from the 40 children in the PPFP pattern revealed that approximately 70 percent fell just short of criterion. Subsequent analysis has shown that two of the five items in the classificatory subtest were ambiguous because item instructions could have been legitimately interpreted to include responses that were, in fact, scored as incorrect. (The classificatory items have been discarded or revised for future use in the cutting tool battery.) The large number of children who failed the classificatory level but who mastered the formal level is, then, attributed to their barely missing attainment at the classificatory level which is, in turn, attributed to ambiguous subtest items.

All children who showed the PPFP pattern

TABLE 12

NUMBER OF ITEMS AND CRITERIA DEFINING FULL ATTAINMENT FOR EACH CONCEPT LEVEL AND USE

Subtest	Number of Items	Criteria for Full Attainment
1. Concrete	7	6 correct
2. Identity	7	6 correct
3. Classificatory	5	4 correct
4. Formal		
a. Discriminating Attributes	5	4 correct
b. Labels	6	5 correct
c. Definition	1	1 correct
5. Principle	5 pairs	4 correct
6. Problem Solving	5	4 correct
7. Supraordinate-Subordinate	4 pairs	3 correct

TABLE 13

NUMBER AND PROPORTION OF FOUR GRADE GROUPS CONFORMING AND NOT CONFORMING TO PREDICTED SEQUENCE OF ATTAINMENT

	K (n=100)	3rd (n=100)	6th (n=100)	9th (n=100)	All Grades (n=400)
FFFF	6 .06	0 .00	0 .00	0 .00	6 .02
PFFF	8 .08	2 .02	0 .00	0 .00	10 .00
PPFF	47 .47	29 .29	12 .12	5 .05	93 .23
PPPF	24 .24	37 .37	23 .23	10 .10	94 .24
PPPP	2 .02	20 .20	49 .49	72 .72	143 .36
Subtotal Conforming	87 .87	88 .88	84 .84	87 .87	346 .87
FFFP	0 .00	0 .00	0 .00	0 .00	0 .00
FFPF	1 .01	0 .00	0 .00	0 .00	1 .00
FFPP	0 .00	0 .00	0 .00	0 .00	0 .00
FPFF	6 .06	0 .00	0 .00	0 .00	6 .02
FPFP	0 .00	0 .00	0 .00	0 .00	0 .00
FPPF	2 .02	1 .01	0 .00	0 .00	3 .01
FPPP	0 .00	0 .00	0 .00	0 .00	0 .00
PFFP	0 .00	0 .00	0 .00	0 .00	0 .00
PFPF	4 .04	0 .00	0 .00	0 .00	4 .01
PFPP	0 .00	0 .00	0 .00	0 .00	0 .00
PPFP	0 .00	11 .11	16 .16	13 .13	40 .10
Subtotal Not Conforming	13 .13	12 .12	16 .16	13 .13	54 .14

of exception were either third, sixth, or ninth graders, as Table 13 shows, and all cases of nonconforming patterns of attainment in these three highest grade groups (except for one third grader) were exclusively in the PPFP pattern. Kindergarteners contributed 13 cases of nonconformity, and these were distributed over four of the remaining patterns of exception.

Table 14 presents frequencies of subjects for each pattern of exception observed in the present assessment and number of items correct at each concept level for which attainment criterion was not met. Examination of these protocols may provide some explanation for their occurrence. Eight subjects failed the concrete subtest but went on to pass one or more higher level. Of these, three barely missed criterion for attainment by passing only five items when six were required. The remaining subjects fell somewhat farther short of criterion. Five subjects failed the identity subtest but went on to attain a higher level. Four of these children came very close to criterion for the identity level, as Table 14 shows. As has already been noted, 40 children failed the classificatory level but went on to pass the formal level. Four of the subtest items were required for attainment and 27 of the 40 subjects missed criterion by just one item. An additional 12 missed criterion by two items and one child passed none of the classificatory items but went on to attain the formal level. As inspection of Table 14 reveals, the majority of cases falling in patterns of exception just barely missed criterion. Such instances are probably most reasonably explained as consequences of measurement error, stringency of criteria, or both. Explanations for those cases that fell far short of criterion must reside, at this point, in presuming inattention to directions or misunderstanding test instructions. In addition, the several ambiguous items on the classificatory subtest, described earlier, are responsible for the large number of cases in the PPFP pattern of exception.

Predicted Sequence of Concept Attainment and Difficulty of the Levels

The CLD hypothesis is that the sequence of attainment is invariant because each successively higher concept level requires the use of one or more increasingly complex cognitive operations. As a consequence the items and the total subtest at each successive level are more difficult. It might be argued that the invariant sequence of attainment is not a function of difficulty determined by increasingly complex cognitive operations at the successive concept levels, concrete through formal, but that it is simply a function

TABLE 14

FREQUENCIES OF SUBJECTS ACCORDING TO PATTERN OF EXCEPTION AND ITEMS CORRECT AT EACH CONCEPT LEVEL NOT ATTAINED

N	Pattern of Exception	Number of Items Correct on Concrete Subtest (6 required)					
		0	1	2	3	4	5
5	FPFF				1	3	1
2	FPPF						2
1	FFPF					3	
		Number of Items Correct on Identity Subtest (6 required)					
		0	1	2	3	4	5
1	FFPF			1			
4	PFPF					1	3
		Number of Items Correct on Classificatory Subtest (4 required)					
		0	1	2	3		
40	PPFP	1		12	27		

of increasing test item difficulty unrelated to the operations. In order to ensure that the number of subjects conforming and not conforming to the predicted sequence was not merely due to increasing difficulty of the successive subtests unrelated to the more complex operations, a statistical procedure accounting for independent difficulty level was applied to data from the present assessment.

Computations were performed using the overall grade group proportions passing and failing each of the four subtests so that a wide range of conceptual attainment would be obtained. These computations yielded expected numbers of subjects following each of the 16 possible patterns of attainment (5 acceptable, 11 unacceptable to the model). It was noted that fewer than 5 subjects were expected to follow each of 9 of the ' c patterns. To meet the requirements . he Chi-square test, patterns were combi d so that the minimum expected number of subjects in each cell would approximate five. Ten patterns and combinations of patterns resulted and were used for the test. A Chi-square goodness of fit test was used to determine whether the obtained number of subjects who followed these patterns differed significantly from the number of subjects expected to follow these patterns. The resulting Chi-square provided convincing evidence that the number of subjects following and not following acceptable patterns was not a function of increasing difficulty of test items unrelated to the operations ($X^2 = 53.68$, d.f. = 5, $p < .001$).

Proportion of Grade Groups Attaining the Four Levels

The number and proportion of each grade group that fully attained each concept level are presented in Table 15. These data will be used to evaluate two interrelated predictions: within a given grade group the percentage of children passing each successive level should decrease and, at the same time, the percentage of children passing a given level should increase as a function of increasing grade group.

Inspection of the row entries of Table 15 shows that within each grade group, as predicted, fewer children attain concept levels as the levels become more difficult. Within the ninth grade group, however, 82 percent attain classificatory compared to 85 percent attaining the formal level. [This reversal to the predicted direction reflects a problem (described earlier) with the criterion for classificatory attainment, in turn due to

TABLE 15

NUMBER AND PROPORTION OF EACH GRADE GROUP THAT FULLY MASTERED EACH LEVEL OF ATTAINMENT

Grade	Concrete	Identity	Classificatory	Formal
K (n=100)				
Number	85	81	33	2
Proportion	.85	.81	.33	.02
3rd (n=100)				
Number	99	98	58	31
Proportion	.99	.98	.58	.31
6th (n=100)				
Number	100	100	72	65
Proportion	1.00	1.00	.72	.65
9th (n=100)				
Number	100	100	82	85
Proportion	1.00	1.00	.82	.85
All Grades (n=400)				
Number	384	379	245	183
Proportion	.96	.95	.61	.46

ambiguity associated with several subtest items in the cutting tool battery.] Data based on the performances of all grade groups also demonstrate the predicted direction: 96 percent attained concrete; 95 percent, identity, 61 percent, classificatory; and 46 percent, formal.

Cochran Q tests were used to find out it the proportions of subjects fully attaining the four concept levels differed significantly within each of the four grade groups. Significance of the differences among the proportions for each of the four grade groups was beyond the .001 level [Q = 174.30, kindergarten; 145.82, third grade; 73.95, sixth grade; 37.31, ninth grade (d.f. = 3)]. McNemar tests were run at the .05 level of significance to discover where specific differences in attainment among the four levels occurred within each of the four grade groups. Six comparisons were possible: concrete with (1) identity, (2) classificatory and (3) formal; identity with (4) classificatory and (5) formal; finally, classificatory with (6) formal. In the kindergarten and third grade groups, every comparison showed a significant difference except that between concrete and identity levels. That is, every comparison within each of these grade groups indicated fewer children attained the higher concept level. In the sixth and ninth grade groups, four comparisons were significantly different in attainment of levels: concrete and classificatory; concrete and formal; identity and classificatory; and identity and formal. Again, the higher the concept level, the fewer the children who attained it.

According to prediction, the percentage of children passing any given level of concept attainment should increase as a function of increasing grade group. Information in the columns of Table 15 is relevant to this prediction. Inspection shows a consistent pattern, at each concept level, for the percentages attaining a level to increase as grade group increases; however, both sixth and ninth graders were equally proficient at concrete and identity levels. The predicted increment is especially pronounced at the formal level: 2 percent of kindergarteners, 31 percent of third graders, 65 percent of sixth graders, and 85 percent of ninth graders attained the concept of cutting tool at the highest level.

Chi-square tests were used to determine whether the proportions of individual grade groups passing each of the four levels of concept attainment differed significantly from the proportions of the combined grade groups passing each of the four levels. The difference in proportions attaining each of the levels was significant beyond the .001 level [Chi-square = 42.19, concrete; 51.21, identity; 57.08, classificatory; 162.89, formal (d.f. = 3)]. In order to discover where differences among grade groups in attainment of each of the four levels were significant at the .05 level, a Chi-square analog to Scheffé's theorem was used. Statistically significant results were as follows: at the concrete, identity, and classificatory levels, the third, sixth, and ninth grade groups each surpassed attainment of kindergarteners. In addition, ninth graders were superior to third graders in performance at the classificatory level. At the formal level, all pair-wise comparisons of grade groups were significantly different; that is, the higher the grade group, the greater the proportion of children attaining the formal level.

The two predictions that are concerned with increasing difficulty of the concept levels are supported by the data assessing full attainment of the concept, cutting tool.

Relationship Between Full Attainment of Various Levels and Full Attainment of the Various Uses

Two predictions dealing with the relation between level of concept attainment and use of the concept are the focus of this section. First, the CLD model specifies that individuals who have attained a concept only to the concrete or to the identity level may be able to use that concept in cognizing simple perceptual relations among concepts and in solving simple problems of a perceptual kind, but that they will not be able to use the concept in understanding supraordinate-subordinate relations, understanding more complex principles, or in solving more complex problems. The second prediction is that concept uses will be mastered by a higher percentage of children attaining the formal level as compared to those attaining at the classificatory level.

The first half of Table 16 is relevant to the first prediction. Among children at all grade groups, ten mastered the concrete level as their highest level of attainment. Of these, one child was able to pass a uses subtest (supraordinate-subordinate). Ninety-nine subjects mastered the identity level as their highest level. Among these children, there were 33 instances of attainment on uses subtests (20, supraordinate-subordinate; 13, problem-solving). This is a fairly large number demanding careful examination of subject performances.

Twenty-three subjects were responsible

TABLE 16

RELATIONSHIP BETWEEN FULL MASTERY OF VARIOUS LEVELS AND FULL MASTERY OF USES

Grade	Concrete as Highest			Identity as Highest			Classificatory But Not Formal			Formal		
	Supra-Sub	Prin.	Prob. Solv.	Supra-Sub	Prin.	Prob. Solv.	Supra-Sub	Prin.	Prob. Solv.	Supra-Sub	Prin.	Prob. Solv.
K												
N Passing Level	8			53			31			2		
N Passing Use	0	0	0	1	0	0	1	0	0	0	0	0
Proportion	.00	.00	.00	.02	.00	.00	.03	.00	.00	.00	.00	.00
3rd												
N Passing Level	2			29			38			31		
N Passing Use	1	0	0	9	0	6	20	0	8	14	2	12
Proportion	.50	.00	.00	.31	.00	.21	.53	.00	.21	.45	.06	.39
6th												
N Passing Level	0			12			23			65		
N Passing Use	0	0	0	8	0	5	12	4	10	37	16	41
Proportion	.00	.00	.00	.67	.00	.42	.52	.17	.43	.57	.25	.63
9th												
N Passing Level	0			5			10			85		
N Passing Use	0	0	0	2	0	2	8	3	5	71	36	67
Proportion	.00	.00	.00	.40	.00	.40	.80	.30	.50	.84	.42	.79
All Grades												
N Passing Level	10			99			102			183		
N Passing Use	1	0	0	20	0	13	41	7	23	123	54	120
Proportion	.10	.00	.00	.20	.00	.13	.40	.07	.23	.67	.30	.66

for the 33 instances of mastery of uses by identity level attainers; in several cases the same subject attained criterion on more than one uses subtest. Close scrutiny of test protocols on these 23 children may provide some explanation for their performance. Of the 23 identity-level subjects who mastered uses, nearly three-quarters (15 subjects) were found to have just barely missed attainment at the classificatory level (four items were required, and these subjects passed three). The remaining eight subjects fell farther short of criterion. Earlier in this chapter it will be recalled that certain problems of ambiguity were associated with two items of the classificatory subtest. Item instructions could have been legitimately interpreted to include responses that were, in fact, scored as incorrect. It is reasonable to attribute mastery of the uses subtests by children at the identity level to their barely missing attainment at the classificatory level, which was, in turn, due to ambiguous items.

Comparing performances of individuals attaining the classificatory level with those attaining the formal level permits an evaluation of the second prediction: concept uses should be attained by a higher percentage of children at the formal level than those at the classificatory level. The second half of Table 16 indicates that the supraordinate-subordinate subtest was passed by 40 percent of those who attained at the classificatory level and 67 percent of those at the formal level. The principle subtest was passed by 7 percent of those at the classificatory level, whereas 30 percent of formal level children passed this subtest. Finally, 23 percent of those individuals who attained at the classificatory level, compared to 66 percent of those attaining at the formal, were able to solve problems successfully.

For each of the three concept uses, Chi-square tests also revealed a significant advantage (beyond the .001 level) for children performing at the formal level when compared to those performing at the classificatory level [Chi-square = 18.74, supraordinate-subordinate; 19.97, principle; 56.34, problem-solving (d.f. = 1)].

Data obtained from assessment of the cutting tool concept provide strong support for the prediction that, in comparison with attainment at the classificatory level, attainment of a concept at the formal level has a facilitative effect on ability to use the concept.

Difficulty of the Three Uses

The CLD model predicts that performance on the uses subtests will improve as a function of increasing grade group. Table 17 persents the number and proportion of subjects at each grade who fully mastered each of the three concept uses: supraordinate-subordinate, principle, and problem-solving. Inspection shows that with each successively higher grade group there was a sizable and consistent increase in percentage of subjects meeting criteria for attainment. For example, 0 percent of the kindergarten group, 26 percent of the third grade, 56 percent of the sixth grade and 74 percent of the ninth grade fully attained the problem-solving subtest. The same type of pattern obtains for the other two uses subtests.

Examination of Table 17 also shows that 46 percent of all subjects attained the supraordinate-subordinate subtest; 15 percent, the principle subtest; and 39 percent, the problem-solving subtest. These data indicate an impressive attainment on uses, but must be viewed as specific to the particular concept, subtest items, and criteria for mastery.

Chi-square tests were used to find the significance of the difference between the proportions of individual grade groups passing each of the three uses and the proportion of the combined grade groups passing each of the three concept uses. The difference in the proportion of subjects attaining each of the uses was significant beyond the .001 level [Chi-square = 132.29, supraordinate-subordinate; 76.97, principle; 134.68, problem-solving (d.f. = 3)]. A Chi-square analog to Scheffé's theorem was performed between all pairs of grade groups to discover where the differences in performance on the uses subtests were significant at the .05 level. Statistically significant results were as follows: for the supraordinate-subordinate subtest, the performances of third, sixth, and ninth grade groups were each superior to that of kindergarteners. In addition, performance of ninth graders surpassed that of both third and sixth grade groups. For the principle subtest, the performance of ninth graders was superior to that of each of the other grade groups; attainment of sixth graders also surpassed that of third graders and kindergarteners. For the problem-solving subtest, all pair-wise comparisons of grade groups were statistically significant. That is, the higher the grade group, the greater the proportion of children attaining the problem-solving subtest.

TABLE 17

NUMBER AND PROPORTION OF EACH GRADE GROUP THAT FULLY MASTERED EACH OF THE THREE CONCEPT USES

Grade	Supraordinate-Subordinate	Principle	Problem Solving
K (n=100)			
Number	2	0	0
Proportion	.02	.00	.00
3rd (n=100)			
Number	44	2	26
Proportion	.44	.02	.26
6th (n=100)			
Number	57	20	56
Proportion	.57	.20	.56
9th (n=100)			
Number	81	39	74
Proportion	.81	.39	.74
All Grades (n=400)			
Number	184	61	156
Proportion	.46	.15	.39

Data obtained from performance on uses subtests clearly support the prediction of an increased ability to use the concept with increasing grade group.

Relationship Between Vocabulary Development and Attainment of Concept Levels and Uses

This section of the present chapter is addressed to the predicted relation between vocabulary proficiency and attainment of the levels and performance of the uses. In order to compute correlation coefficients, the same scaling system was used for cutting tool as that described in Chapter III for equilateral triangle. The reader is referred to the earlier chapter for a complete description of the scaling system.

Table 18 presents means and standard deviations, based on the scaled scoring system, for levels, uses, combined levels and uses, and vocabulary scores at each grade group. Performance on the six-item vocabulary test of the cutting tool assessment battery was fairly proficient at each of the four grade groups, although Table 18 does show some gradual improvement over grades. In addition, these data based on mean scaled scores confirm our earlier finding that attainment of concept levels increases with successive grade groups, as did attainment of the uses. Similarly, overall test performance (combined levels and uses) indicates an improvement with increasing grade group.

Pearson product-moment correlations were calculated between vocabulary scores and scores on (1) concept level, (2) concept uses, and (3) combined levels and uses. These correlations for each grade group and over all grade groups are shown in Table 19. Eight of the correlations within grade groups were sufficiently high to achieve statistical significance from zero at or beyond the .01 level. Correlations at the ninth grade, however, are of a much lower magnitude. Vocabulary scores and scores on the levels and uses showed very little variability in this grade group, as can be observed in Table 18. The low correlations obtained for the ninth grade group reflect this lack of variability.

As predicted, correlations obtained for the total subject population were much greater in magnitude than those within grade groups, and all were statistically significant from zero at or beyond the .01 level. The correlation between vocabulary and overall performance on concept level subtests was .68. Vocabulary correlated .52 with overall performance on concept uses, and .67 with overall performance on levels and uses. The predicted relationship between vocabulary proficiency and concept attainment and use is strongly supported by these data.

TABLE 18

MEANS AND STANDARD DEVIATIONS FOR COMBINED CONCEPT LEVELS, CONCEPT USES, LEVELS AND USES, AND VOCABULARY AT EACH GRADE GROUP

Grade	N	Concept Levels: (Maximum score, 4)		Concept Uses: (Maximum score, 3)		Levels and Uses: (Maximum score, 7)		Vocabulary: (Maximum score, 6)	
		M	S.D.	M	S.D.	M	S.D.	M	S.D.
K	100	1.16	.68	.02	.14	1.18	.70	3.08	1.86
3rd	100	1.87	.75	.72	.81	2.59	1.19	4.77	1.43
6th	100	3.37	.69	1.33	.95	4.70	1.25	5.53	.80
9th	100	3.67	.57	1.94	.87	5.61	1.21	5.84	.51
All Grades	400	2.52	1.24	1.00	1.04	3.52	2.06	4.81	1.66

TABLE 19

PEARSON PRODUCT-MOMENT CORRELATIONS BETWEEN MEAN VOCABULARY SCORES AND MEAN SCORES ON CONCEPT LEVELS, CONCEPT USES, AND COMBINED LEVELS AND USES

Grade Group	N	Four Concept Levels	Three Concept Uses	Combined Levels and Uses
K	100	.48**	.15	.49**
3rd	100	.46**	.29**	.49**
6th	100	.52**	.31**	.53**
9th	100	.17	.14	.18
All Grades	400	.68**	.52**	.67**

**p < .01

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V
Summary and Conclusions

In this chapter a brief summary of the study precedes a discussion of results of both assessment batteries as they bear on our conclusions concerning each of the eight CLD predictions.

Summary

The CLD model encompasses three major propositions dealing with patterns of children's conceptual learning and development. Related to each proposition there are several specific predictions. Inasmuch as the major propositions and predictions are discussed in some detail in prior chapters, the predictions are stated in summary fashion as follows:

1. All children of all grade groups will conform to five acceptable patterns of mastery of four concept levels.
2. The number and proportion of children within a grade group who pass each successive level of concept attainment will decrease.
3. The number and proportion of children of successively higher grade groups mastering each concept level will increase.
4. A higher proportion of children who attain a concept at the formal level in comparison with those who attain at the classificatory level will also master each of the three concept uses.
5. Children who attain a concept to only the concrete and/or identity level will be able to use that concept only in understanding simple perceptual relationships with other objects and in solving simple perceptual problems.
6. The number and proportion of children of successively higher grade groups who master each concept use will increase.
7. Vocabulary scores and scores based on attainment of the four levels and the three uses will correlate positively within grade groups.
8. Vocabulary scores and scores based on the levels and uses will correlate positively for the combined grade groups.

The preceding predictions were tested, using two specially constructed assessment batteries. One battery was used for each concept: equilateral triangle and cutting tool. Each battery also had one subtest for each of the four levels of concept attainment and for each of three uses of an attained concept. Thus, a total of 14 tests was developed, seven for each of the two concepts.

One hundred children at each of four grade levels--kindergarten, third, sixth, and ninth--participated in the study. Children in the three lower grades were enrolled in four different elementary schools. The ninth grade students were enrolled in a high school. The schools and classrooms in which the children were enrolled were judged to be typical of the particular school system and also of a large number of classrooms in small towns of Wisconsin and other states.

The tests of the various batteries were administered to children in intact classroom groups; except that kindergarten children received the tests in small groups of about five to eight. On each subtest a child's responses were scored as passing or failing. Criteria were established to determine passing and failing as has been reported in chapters III and IV. The data were quantified by computing frequencies and proportions of subjects within each grade group who attained each concept level and each use. Post hoc statistical tests were used where appropriate to obtain more specific information about differences in frequencies and proportions. The predicted relationship between vocabulary and performance was evaluated by correlation coefficients.

Conclusions

Results of the two assessments have been presented and discussed separately in the preceding chapters. Now we will consider the concepts simultaneously in order that our conclusions regarding the eight predictions can be stated with a greater degree of generality and confidence and so that relevant cross-concept comparisons can be made. Each prediction is stated, and the evidence based on all three concepts is summarized and discussed.

1. All children of all grade groups will conform to five acceptable patterns of mastery of the four concept levels. This prediction was supported, in general, by results obtained for the two concepts assessed in the present study. Table 20 summarizes pertinent information for both concepts. Inspection shows that of the 400 participating children, 90 percent conformed to the predicted pass/fail patterns for equilateral triangle and 87 percent conformed for cutting tool.

   Table 21 presents the frequencies of the total subject population who deviated from the predicted patterns. Ten percent of the 400 children (40 subjects) did not conform to the predicted sequence in the assessment of equilateral triangle. These subjects were fairly equally distributed over six of the possible eleven patterns of exception. Fourteen percent (54 children) of the total subject population did not conform in the assessment of cutting tool. Nonconformers fell into five unacceptable patterns; however, a majority of the children who deviated from prediction on cutting tool fell into a single pattern of exception (PPFP). As discussed at length in chapter IV, the large number of children in this pattern was due to certain ambiguous classificatory subtest items. Of the eleven possible patterns of deviation from the predicted sequence of attainment, five contributed to deviations in both equilateral triangle and cutting tool.

   Further examination of protocols from the 94 children who did not conform to the predicted patterns of attainment revealed that six subjects followed unacceptable patterns in both concept assessments. That is, there was a six percent overlap in nonconformity to predicted patterns for the two assessment batteries. This is a small percentage and is taken to indicate a fairly high degree of independence between the two concept batteries; it seems reasonable to conclude that exceptions to the predicted patterns are probably the result of errors of measurement or problems associated with the criteria established for concept level attainment, and not the result of true exceptions in terms of sequential development. Had all or most of the deviating children been identical for the two assessments, the unavoidable conclusion would be that these children were truly not conforming to the hypothesized invariant sequence of conceptual development.
2. The number and proportion of children within a single grade group who passed each successive level of concept attainment will decrease. This prediction, in general, was supported by data for each of the four grade groups when the two concepts were examined individually. The row entries of Table 22 permit cross-concept comparisons for the proportions of each grade group that fully mastered each level of attainment. There might have been 32 exceptions to this prediction, based on the total number of entries in the table. Only one minor reversal occurred. In the cutting tool assessment, 82 percent of the ninth grade subjects passed the classificatory level, whereas 85 percent passed the formal level. For both equilateral triangle and cutting tool, sixth and ninth graders were equally proficient at the concrete and identity levels. The single exception to the predicted direction of attainment has been discussed in chapter IV; it reflects a problem with the criterion for classificatory attainment, in turn due to ambiguity associated with certain subtest items in the cutting tool battery.
3. The number and proportion of successively higher grade groups mastering each concept level will increase. The summary information in Table 22 is also relevant for a final evaluation of this prediction. Inspection of the

TABLE 20

PROPORTION OF TOTAL SUBJECT POPULATION CONFORMING TO PREDICTED PASS-FAIL PATTERNS OF ATTAINMENT: COMPARING EQUILATERAL TRIANGLE AND CUTTING TOOL

	Concept	
Pass-Fail Sequence	Equilateral Triangle (N = 400)	Cutting Tool (N=400)
FFFF	.01	.02
PFFF	.02	.03
PPFF	.16	.23
PPPF	.38	.24
PPPP	.33	.36
Total	.90	.87

TABLE 21

FREQUENCIES OF TOTAL SUBJECT POPULATION SHOWING PASS-FAIL PATTERNS OF EXCEPTION: COMPARING EQUILATERAL TRIANGLE AND CUTTING TOOL

Pass-Fail Pattern of Exception	Equilateral Triangle (N=400)	Cutting Tool (N=400)	Total
FFFP			0
FFPF	4	1	5
FFPP			0
FPFF	8	6	14
FPFP			0
FPPF	8	3	11
FPPP			0
PFFP			0
PFPF	11	4	15
PFPP	1		1
PPFP	8	40	48
Total	40	54	94
Percentage of Total Population	.10	.14	

columns of this table discloses not a single exception to the prediction. Moreover, the increase in attainment of levels with increasing grade group is marked, particularly at the classificatory and formal levels. In conclusion, we find strong support for the prediction that at each concept level the number and proportion of children who master the concept will increase as grade group increases.

4. A higher proportion of children who attain a concept at the formal level in comparison with those who attain it at the classificatory level will also master each of the three uses. This prediction was clearly upheld when each of the concepts was examined individually. Summarizing data for both concepts, Table 23 presents the proportion of children who passed the four levels and who also passed the various uses. As shown at the bottom of this table, nine possible exceptions might have occurred to the prediction that children who attain a concept at the formal level, compared to those attaining at the classificatory level, demonstrate superior performance on the concept uses. Inspection reveals no exceptions to the prediction. Indeed, the differences in the actual percentage values are both consistent and strikingly large. For example, data for equilateral triangle indicate that a marked advantage in mastery of uses occurred for individuals attaining at the formal level: 23 percent passed the supraordinate-subordinate subtest, compared to 3 percent of classificatory attainers; 40 percent passed the principles subtest, compared to 5 percent of classificatory attainers; and 25 percent passed the problem solving subtest, compared to 2 percent of classificatory attainers.

5. Children who attain a concept to only the concrete and/or the identity level will be able to use that concept only in understanding simple perceptual relationships with other object concepts and in solving simple perceptual problems. In general, data supported this prediction, although several exceptions did occur, particularly in the cutting tool battery. The upper half of Table 23 shows that the exceptions were as follows: 10 percent (1 of 10) of the children who attained only to the concrete level of cutting tool passed the supraordinate-subordinate uses subtest; approximately one percent (1 of 73) of the children who attained only to the identity level of equilateral triangle and 20 percent (20 of 99) of the children who attained at the identity level of cutting tool were also able to pass the supraordinate-subordinate subtest. (Detailed explanation for the large percentage of identity-level subjects passing the uses of cutting tool is provided in chapter 4.)

6. The number and proportion of children of successively higher grade groups who master each concept use will increase. This prediction has received strong and consistent support from data assessing the two concepts. Table 24 summarizes data and shows that 24 exceptions to the prediction might have occurred. Inspection reveals no reversals to the predicted trend. Moreover, improvement in mastery of the uses markedly increased with increasing grade group. For example, for the supraordinate-subordinate subtest of cutting tool the the progression was as follows: kindergarten, 2 percent; third grade, 44 percent; sixth grade, 57 percent; ninth grade, 81 percent.

7. Vocabulary scores and scores based on the attainment of the four levels and the three uses will correlate positively within grade group. This prediction was supported by data for both concepts assessed in the present study. Table 25 summarizes the 24 correlations obtained between vocabulary scores and scores on levels, uses, and combined levels and uses at each grade group. No exceptions to the prediction of a positive relationship occurred (i.e., no negative correlations were found). Moreover, the size of the correlations within the various grade groups, in general, was considerably higher than anticipated. Fifteen of the 24 correlations were statistically significant from zero at or beyond the .05 level; actual values ranged from .22 to .53. In the equilateral triangle assessment, very low correlational values were obtained for the kindergarten group; in the cutting tool assessment, relatively low correlational values were obtained for the ninth grade group. In both cases, as explained in chapters III and IV, range of performance on

TABLE 22

PROPORTION OF EACH GRADE GROUP THAT FULLY MASTERED EACH LEVEL OF ATTAINMENT: COMPARING EQUILATERAL TRIANGLE AND CUTTING TOOL

Grade Group	Concrete	Identity	Classificatory	Formal
K				
N = 100 Equilateral Triangle	.82	.81	.42	.00
100 Cutting Tool	.85	.81	.33	.02
3rd				
N = 100 Equilateral Triangle	.94	.92	.78	.15
100 Cutting Tool	.99	.98	.58	.31
6th				
N = 100 Equilateral Triangle	1.00	1.00	.90	.46
100 Cutting Tool	1.00	1.00	.72	.65
9th				
N = 100 Equilateral Triangle	1.00	1.00	.98	.81
100 Cutting Tool	1.00	1.00	.82	.85

TABLE 23

RELATIONSHIP BETWEEN FULL MASTERY OF LEVELS AND FULL MASTERY OF USES: COMPARING PROPORTIONS OF TOTAL SUBJECT POPULATION PASSING USES FOR EQUILATERAL TRIANGLE AND CUTTING TOOL

Concept	Concrete as Highest			Identity as Highest		
	Supra-Sub	Prin.	Probl. Solv.	Supra-Sub	Prin.	Prob. Solv.
N Passing Level	7			73		
N Passing Use	0	0	0	1	1	1
Equilateral Triangle	.00	.00	.00	.01	.01	.01
N Passing Level	10			99		
N Passing Use	1	0	0	20	0	13
Cutting Tool	.10	.00	.00	.20	.00	.13

Concept	Classificatory as Highest			Formal as Highest		
	Supra-Sub	Prin.	Probl. Solv.	Supra-Sub	Prin.	Prob. Solv.
N Passing Level	174			142		
N Passing Use	5	8	4	33	57	35
Equilateral Triangle	.03	.05	.02	.23	.40	.25
N Passing Level	102			183		
N Passing Use	41	7	23	122	54	120
Cutting Tool	.40	.07	.23	.67	.30	.66

TABLE 24

PROPORTION OF EACH GRADE GROUP
THAT FULLY MASTERED EACH OF THE THREE CONCEPT USES:
COMPARING EQUILATERAL TRIANGLE AND CUTTING TOOL

Grade Group	Supraordinate-Subordinate	Principle	Problem-Solving
K			
N = 100 Equilateral Triangle	.00	.00	.00
100 Cutting Tool	.02	.00	.00
3rd			
N = 100 Equilateral Triangle	.03	.00	.00
100 Cutting Tool	.44	.02	.26
6th			
N = 100 Equilateral Triangle	.09	.10	.02
100 Cutting Tool	.57	.20	.56
9th			
N = 100 Equilateral Triangle	.27	.56	.38
100 Cutting Tool	.81	.39	.74

TABLE 25

PEARSON PRODUCT-MOMENT CORRELATIONS AT EACH GRADE GROUP BETWEEN MEAN
VOCABULARY SCORES AND MEAN SCORES ON CONCEPT LEVELS, CONCEPT USES, AND
COMBINED LEVELS AND USES: COMPARING EQUILATERAL TRIANGLE AND CUTTING TOOL

Grade Group	Four Concept Levels	Three Concept Uses	Combined Levels and Uses
K			
N = 100 Equilateral Triangle	.09	.00	.09
100 Cutting Tool	.48**	.15	.49**
3rd			
N = 100 Equilateral Triangle	.27**	.22*	.30**
100 Cutting Tool	.46**	.29**	.49**
6th			
N = 100 Equilateral Triangle	.33**	.17	.33**
100 Cutting Tool	.52**	.31**	.53**
9th			
N = 100 Equilateral Triangle	.17	.43**	.45**
100 Cutting Tool	.17	.14	.18

*$p < .05$
**$p < .01$

vocabulary was responsible for the low order correlations in both sets of data.

8. Vocabulary scores and scores based on the attainment of the four levels and the three uses will be positively correlated and higher across combined grade groups. This prediction received strong support from both concept assessments, as summarized in Table 26. Magnitude of the correlations is similar for both equilateral triangle and cutting tool. Correlations across grade groups are highest for vocabulary scores and combined levels and uses scores. The six correlations entered in this table are notably larger in magnitude than those obtained within grade groups and all of them are statistically significant from zero at or beyond the .01 level.

TABLE 26

CORRELATIONS FOR TOTAL SUBJECT POPULATION BETWEEN MEAN VOCABULARY SCORES AND MEAN SCORES ON LEVELS, USES, AND COMBINED LEVELS AND USES: COMPARING EQUILATERAL TRIANGLE AND CUTTING TOOL

Concept	Four Concept Levels	Three Concept Uses	Combined Levels and Uses
N = 324 Equilateral Triangle	.58**	.52**	.69**
N = 363 Cutting Tool	.68**	.52**	.67**

**P < .01

References

Ausubel, D. P. ... psychology of meaningful verbal learning. New York: Grune & Stratton, 1963.

Ausubel, D. P. Meaningful reception learning and the acquisition of concepts. In H. J. Klausmeier & C. W. Harris (Eds.), Analyses of concept learning. New York: Academic Press, 1966. Pp. 157-175.

Bourne, L. E., Jr., Ekstrand, B. R., & Dominowski, R. L. The psychology of thinking. Englewood Cliffs, N.J.: Prentice-Hall, 1971.

Bourne, L. E., Jr., & Restle, F. Mathematical theory of concept identification. Psychological Review, 1959, 66(5) 278-296.

Bruner, J. S. The course of cognitive growth. American Psychologist, 1964, 19, 1-15.

Bruner, J. S., Goodnow, J. J., & Austin, G. A. A study of thinking. New York: Wiley, 1956.

Bruner, J. S., Olver, R. R., Greenfield, P. M., et al. Studies in cognitive growth. New York: Wiley, 1966.

Campbell, D., & Stanley, J. Experimental and quasi-experimental designs for research on teaching. In N. Gage (Ed.), Handbook of research on teaching. Chicago: Rand McNally, 1963. Pp. 171-246.

Carroll, J. B. Words, meanings, and concepts. Harvard Educational Review, 1964, 34, 178-202.

Deese, J. Meaning and change of meaning. American Psychologist, 1967, 22, 641-651.

Elkind, D. Conservation and concept formation. In D. Elkind & J. H. Flavell (Eds.), Studies in cognitive development: Essays in honor of Jean Piaget. London and New York: Oxford University Press, 1969, Pp. 171-189.

Feldman, K. V. The effects of number of positive and negative instances, concept definition, and emphasis of relevant attributes on the attainment of mathematical concepts. Technical Report No. 243. Madison: Wisconsin Research and Development Center for Cognitive Learning, 1972.

Flavell, J. H. Concept development. In P. H. Mussen (Ed.), Carmichael's manual of child psychology. Vol. 1. New York: Wiley, 1970, Pp. 983-1059.

Gagné, R. M. The learning of principles. In H. J. Klausmeier & C. W. Harris (Eds.), Analyses of concept learning. New York: Academic Press, 1966, Pp. 81-95.

Gagné, R. M. The conditions of learning. (2nd ed.) New York: Holt, Rinehart and Winston, 1970.

Gesell, A. Infancy and human growth. New York: Macmillan, 1928.

Gesell, A. The embryology of behavior: The beginnings of the human mind. New York: Harper, 1945.

Gibson, E. J. Principles of perceptual learning and development. New York: Appleton, 1969.

Golub, L. S., Fredrick, W., Nelson, N., & Frayer, D. A. Selection and analysis of language arts concepts for inclusion in tests of concept attainment. Working Paper No. 59. Madison: Wisconsin Research and Development Center for Cognitive Learning, 1971.

Goodnow, J. J. Problems in research on culture and thought. In D. Elkind & J. H. Flavell (Eds.), Studies in cognitive development. New York: Oxford University Press, 1969, Pp. 439-462.

Guilford, J. P. The nature of human intelligence. New York: McGraw-Hill, 1967.

Hooper, F. H., & Klausmeier, H. J. Description and rationale for a longitudinal assessment of children's cognitive development and concept learning. Working Paper No. 113. Madison: Wisconsin Research and Development Center for Cognitive Learning, 1973.

Hunt, E. B. Concept learning: An information-processing problem. New York: Wiley, 1962.
Inhelder, B., & Piaget, J. The early growth of logic in the child: Classification and seriation. New York: Harper & Row, 1964.
Kagan, J. A developmental approach to conceptual growth. In H. J. Klausmeier & C. W. Harris (Eds.), Analyses of concept learning. New York: Academic Press, 1966, Pp. 97-116.
Kagan, J., Moss, H. A., & Sigel, I. E. Psychological significance of styles of conceptualization. Monograph of the Society for Research in Child Development, 1963, 28(Whole No. 86), Pp. 73-112.
Klausmeier, H. J. Cognitive operations in concept learning. Educational Psychologist, November 1971, Pp. 1 and 3-8.
Klausmeier, H. J., Bernard, M. E., Katzenmeyer, C. G., & Sipple, T. S. Development of Conceptual Learning and Development Assessment Series II: Cutting Tool. Working Paper No. 120. Madison: Wisconsin Research and Development Center for Cognitive Learning, 1973.
Klausmeier, H. J., Davis, J. K., Ramsay, J. G., Fredrick, W. C., & Davies, M. H. Concept learning and problem solving: A bibliography, 1950-1964. Wisconsin Research and Development Center for Cognitive Learning, Technical Report No. 1, 1965.
Klausmeier, H. J., Ghatala, E. S., & Frayer, D. A. Conceptual learning and development: A cognitive view. New York: Academic Press, 1974.
Klausmeier, H. J., Ingison, L. J., Sipple, T. S., & Katzenmeyer, C. G. Development of Conceptual Learning and Development Assessment Series I: Equilateral Triangle. Working Paper No. 119. Madison: Wisconsin Research and Development Center for Cognitive Learning, 1973. (a)
Klausmeier, H. J., & Meinke, D. L. Concept attainment as a function of instructions concerning the stimulus material, a strategy, and a principle for securing information. Journal of Educational Psychology, 1968, 59, 215-222.
Kofsky, E. A scalogram study of classificatory development. Child Development, 1966, 37, 191-204.
Levine, M. Mediating processes in humans at the outset of discrimination learning. Psychological Review, 1963, 70, 254-276.
Levine, M. Hypothesis behavior by humans during discrimination learning. Journal of Experimental Psychology, 1966, 71, 331-336.
Luria, A. R. The role of speech in the regulation of normal and abnormal behavior. New York: Liveright, 1961.
Markle, S. M., & Tiemann, P. W. Really understanding concepts: Or in frumious pursuit of the jabberwock. Champaign, Ill.: Stipes, 1969.
Marx, M. H. (Ed.) Learning: Theories. New York: Macmillan, 1970.
Osgood, C. E. Method and theory in experimental psychology. New York: Oxford University Press, 1953.
Piaget, J. Piaget's theory. In P. H. Mussen (Ed.), Carmichael's manual of child psychology. New York: Wiley, 1970, Pp. 703-732.
Romberg, T. A., Steitz, J., & Frayer, D. A. Selection and analysis of mathematics concepts for inclusion in tests of concept attainment. Working Paper No. 55. Madison: Wisconsin Research and Development Center for Cognitive Learning, 197[illegible].
Staats, A. Child learning, intelligence and personality. New York: Harper & Row, 1971.
Swanson, J. E. The effects of number of positive and negative instances, concept definition, and emphasis of relevant attributes on the attainment of three environmental concepts by sixth-grade children. Technical Report No. 244. Madison: Wisconsin Research and Development Center for Cognitive Learning, 1972.
Tabachnick, B. R., Weible, E., & Frayer, D. A. Selection and analysis of social studies concepts for inclusion in tests of concept attainment. Working Paper No. 53. Madison: Wisconsin Research and Development Center for Cognitive Learning, 1970.
Tagatz, G. E. Effects of strategy, sex, and age on conceptual behavior of elementary school children. Journal of Educational Psychology, 1967, 58, 103-109.
Tennyson, R. D., & Boutwell, R. C. A quality control design and evaluation model for hierarchical sequencing of programmed instruction. National Society for Programmed Instruction Journal, 1971, 10, 5-10.
Trabasso, T., & Bower, G. Attention in Learning. New York: Wiley, 1968.
Vernon, M. D. Perception through experience. New York: Barnes & Noble, 1970.

Voelker, A. M., Sorenson, J. S., & Frayer, D. A. Selection and analysis of classificatory science concepts by intermediate-grade children. Working Paper No. 57. Madison: Wisconsin Research and Development Center for Cognitive Learning, 1971.

Vygotsky, L. S. (translated by E. Hanfmann & G. Vakar) Thought and language. Cambridge, Mass.: M.I.T. Press, 1962.

Williams, C. F. A model of memory in concept learning. Cognitive Psychology, 1971, 2, 158-184.

Woodruff, A. D. Basic concepts of teaching. (Concise ed.) San Francisco: Chandler Publishing, 1961.

Woodruff, A. D. Cognitive models of learning and instruction. In L. Siegel (Ed.), Instruction: Some contemporary viewpoints. San Francisco: Chandler Publishing, 1967, Pp. 55-98.

Zeaman, D. & House, B. J. The role of attention in retardate discrimination learning. In N. R. Ellis (Ed.), Handbook of mental deficiency. New York: McGraw-Hill, 1963, Pp. 159-223.

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